Hydroacoustic Evaluation of a Prototype Surface Collector at Bonneville Dam First Powerhouse in 2000

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Abstract

Objectives and Methods – The goal of this fixed-aspect hydroacoustic study was to resolve critical uncertainties in the implementation of surface collection at Powerhouse 1 at Bonneville Dam. We address the following objectives in this presentation: 1) estimate the number of smolt-sized fish entering and passing under the Prototype Surface Collector (PSC) in front of Units 1-6 based on in-turbine sampling of all 18 intakes of those units; 2) estimate fish passage efficiency (FPE) for each of the six PSC units and for the entire PSC by season and week; 3) estimate fish passage effectiveness for each of the six PSC units and for the entire PSC by season and week; 4) compare the number of fish collected by the PSC and its FPE with those at Units 7, 9, and 10 (with submerged traveling screens or STS's) and with those at Unit 8 (with an extended submerged bar screen or ESBS); 5) estimate entrance efficiency at each PSC opening and across the whole PSC; 6) describe the horizontal distribution of passage among the six PSC slots and among units at Powerhouse 1.

Sampling was around the clock with a short break each morning for data downloading and archiving and employed 420 kHz fixed-aspect hydroacoustic transducers (Precision Acoustic Systems, Seattle, WA). There were 18 down looking 6.5^o single-beam transducers mounted in-turbine behind the PSC and in every intake of Units 1-6. There were opposed pairs of 6^o split-beam transducers immediately upstream of each of five openings of the PSC (the Unit 3 opening was involved in a separate PNNL study) to provide entrance efficiency data. The units outside the PSC were sampled by opposing pairs of fixed transducers, 6.5^o at Units 7 and 9 and 6^o at Units 8 and 10.

Passage estimates were made from spatial and temporal expansions of counts of fish by automated hydroacoustic tracking software**.** A subset of the raw data was also analyzed by trained technicians for quality-control checks on the automated processing software.

Spring Results: **Metric Estimates-** In spring the PSC (Units 1-6) produced an FGE of 0.72, which was the same as for the ESBS on Unit 8. However, the in-turbine transducers did not sample guided fish passage in the upper 3-m of the intakes nor through the sluice gates above every center intake of each of the six PSC units, so these estimates are very conservative. Preliminary results from radio telemetry indicate that fish passage through the sluiceway at Powerhouse 1 accounted for about 15 % of total fish passage there, which would increase our average estimate from 72 to 87%. FGE estimates varied significantly among PSC units, with 20-ft wide slots at Units 5 and 6 producing significantly higher FGE's than the other 20-ft wide PSC slots. Estimated unit-specific FGE's within the PSC were: Units 5 (0.85) and 6 (0.81) the highest, followed by Unit 2 (0.73), Unit 1 (0.64), and Units 3 and 4 (0.63). Powerhouse 1 units with STS's (Units 7, 9, and 10) had an estimated mean FGE of 0.48. All Turbine Units on Powerhouse 2 employ STS's and had an estimated mean FGE of 0.73.

On average, the PSC was 2.15 times more efficient at passing fish than it was at passing water (i.e. effectiveness was 2.15). Unit-specific effectiveness was 2.55 at Unit 5 and 2.44 at Unit 6 and these estimates were significantly higher than those observed at other units (Unit 2 = 2.16, Unit 1 and 4 = 1.92 and Unit 3 = 1.87).

Horizontal Passage Distribution

We estimate that about 72 % of all fish passing Powerhouse 1 in spring passed south of the wing wall and either through or under the PSC. Passage among the PSC units was roughly uniform with Unit 4 passing the most fish and Unit 1 the least. Of the remaining approximately 28 % that passed north of the wing wall, about 5% passed Unit 7, about 7 % passed Unit 8, about 16 % passed Unit 9, and under 1% passed Unit 10, which was off line for much of the season.

Of the estimated nearly 11.3M fish that were collected by all fish protection structures at PH1 in spring, about 8.7M (or 77.2%) were collected by the PSC with numbers generally increasing from just over 1M at Unit 1 to nearly 1.8M at Unit 6. Of the estimated nearly 2.6 M fish guided at Units 7-10 just over half (1.3M) were guided by the STS at Unit 9. The ESBS guided just over 0.8M fish and Units 7 and 10 (Unit 10 was closed for much of the spring) shared the remaining 42,000.

Summer Results The efficiency of the PSC did not decline from spring through summer. The PSC efficiency averaged 0.72 in both seasons. Within the PSC, unit-specific FGE estimates, as in spring, showed a considerable range with Units 5 and 6 again having the highest FGE's. Estimated unit-specific FGE's within the PSC were 0.83 at Unit 5 and 0.82 at Unit 6 (the highest) followed by Unit 4 (0.72), Unit 3 (0.65), Unit 1 (0.64) and Unit 2 (0.63). Units 7, 9, and 10 (STS's) had an estimated mean FGE of 0.36. All Turbine Units on Powerhouse 2 employ STS's and had an estimated mean FGE of 0.35, although units 12-16 at Powerhouse 2 were off most of the summer. Whereas FGE estimates were the same for the PSC in spring and summer and for the ESBS on Unit 8 in spring (0.72 for all), the ESBS's estimated FGE at Unit 8 was about 22 % lower in summer than in spring. Neither spring nor summer PSC estimates included numbers of guided fish passage through the six open sluice gates in the PSC.

We estimated the effectiveness of the PSC in summer to be 2.24. As in spring, the PSC's unit-specific efficiencies paralleled unit-specific FGE's with the northern units nearer the wing wall having higher estimated effectiveness: Unit 6 (2.66), Unit 5 (2.54), Unit 4 (2.31), Units 3 and 1 (1.99) and Unit 2 (1.93).

Horizontal Passage Distribution

We estimate that about 69% of all fish passing Powerhouse 1 in summer passed south of the wing wall and either through or under the PSC. As in spring, passage among the PSC units was roughly uniform, ranging from about 9% of Powerhouse 1 passage at Unit 1 to about 14% at Unit 4. Of the remaining 31% of Powerhouse 1 fish that passed north of the wing wall in summer, about 5% each passed Unit 7 and Unit 8, about 15% passed Unit 9, and about 6% passed Unit 10.

In summer we estimate that about 8.8M fish were collected by all fish protection structures at PH1 and that about 8.7M (or 80%) were collected by the PSC with numbers ranging from just under 0.82M at Unit 1 to 1.4M at Unit 6. Of the about 1.7 M of the fish guided at Units 7-10 just under half (nearly 800,000) were guided by the STS at Unit 9. Unit 8's ESBS guided about 350,000, Unit 7's STS guided about 367,000, and Unit 10's STS guided just over 200,000 fish.

Movement, Distribution, and Passage Behavior of Radio-Tagged Juvenile Salmonids at Bonneville Dam Associated with the Surface Bypass Program, 2000.

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Abstract

The goal of our study was to determine the efficiency of the prototype surface collector (PSC) at Powerhouse I of Bonneville Dam. We used radio telemetry to monitor the behavior and distribution of juvenile salmonids in the natural river area upstream of the immediate forebay, within the far and near forebay areas, and at surface oriented passage routes like the PSC. A combination of aerial and underwater radio-telemetry equipment was used to monitor the movements of juvenile spring and fall chinook salmon and steelhead. A total of 4,125 radio-tagged juvenile spring and summer chinook salmon and steelhead were released above Bonneville Dam between 25 April and 1 June 2000. These fish included those released at Bonneville Dam as well as others released as part of Army Corps of Engineer funded studies at John Day and The Dalles dams. Of these fish, we have currently analyzed 985 of the spring chinook salmon and steelhead. Based on this limited number of fish, we have determined that the detection efficiency at Bonneville Dam increased from 71% in 1999 to 88% during 2000. Of the radio-tagged spring chinook salmon analyzed so far, 93 (14%) came within 10 m of the upstream face of the PSC. Of these 93 fish, 64 (69%) entered the PSC. This is a significant increase from 1999 when 20-33% of the fish that came within 10 m of the PSC entered. Of the radio-tagged steelhead analyzed so far, 63 (29%) came within 10 m of the upstream face of the PSC. Of these 63 fish, 28 (44%) entered the PSC. Again, this is an increase from 1999 when 19-21% of the fish that came within 10 m of the PSC entered. Although we must complete the analysis of the 2000 data to confirm these preliminary results, it appears that the efficiency of the PSC increased during 2000. This increase may be attributed to the number of openings tested during 2000. There was essentially only one opening to the PSC in 1999 compared to six openings in 2000. However, there is other evidence that the removal of the PSC trash racks for the 2000 study may have improved flow characteristics into the PSC and made a significant contribution to the improved efficiency.

Evaluation of 3-D Fish Behavior in Front of the Prototype Surface Collector at Bonneville Dam, 2000

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The Portland District of the U.S. Army Corps of Engineers is developing surface flow bypass at the Bonneville Dam first and second powerhouses, in response to the 1995 Biological Opinion on operation of the Federal Columbia River Power System. A prototype surface collector (collector) was installed and evaluated in the spring and summer of 1998 (unit 3, first powerhouse) and in the spring of 1999 (unit 5, first powerhouse). The collector is a temporary structure designed to test surface bypass concepts. It spans units 1-6 and has 6 vertical slots, one in front of each of the B-intakes. Results from the 1998 and 1999 studies indicate that fish swimming effort increased at the fish approached an opening, fish were distributed deeper when the slot was 1.5 m wide, than when it was 6 m wide. Milling metrics (tortuosity and loopyness) also increased as the fish approached the collector. The objectives of the study in 2000 are to quantify fish behavior within 18 meters of the collector. This involves estimating the direction of movement, milling behavior, velocity distributions and potential entrance efficiencies within specific regions in front of and to the side of the 6 m collector opening at unit 3.

Hydroacoustic systems were deployed in the forebay and immediately in front of the collector opening at unit 3 during the spring (April 21-June1) and summer (June1 to July15) sampling periods in 2000. A multibeam hydroacoustic system was deployed from a floating platform moored in the forebay, 18m in front of unit 3. Horizontal and vertical coverage was approximately 10 m on a side or 100 m^2. This provided complete side-to-side coverage of the collector opening. A multiplexed split-beam system was used to collect fish target data directly in front of the opening. Three transducers were aimed down from near the surface while a fourth transducer was aimed up from the bottom of the collector. The up-looking transducer was afixed to a traversing system, which covered both the opening as well as an area on each side of the opening. Deployed on the traversing system with the transducer was a narrow footprint acoustic doppler current profiler (ADCP). The ADCP measured flow in the area sampled by the down-looking transducer.

More than 33,000 targets were identified by the split- and multi-beam systems. Most of these targets were detected during the daylight hours especially during the summer period. From the distribution, it appears that targets concentrated close to the collector during the day. Fish were generally headed in the direction of flow as they approach the collector. Analysis of milling behavior indicates that fish far from the collector are more directed in their movement and as they approach the collector, their swimming becomes more tortuous. Differences between day and night suggest that visual cues may play a role in determining fish behavior in the near-field. Fish may be discouraged from entering the PSC at night because of lighting, operations, etc. It will be important to understand this phenomena for the final design of the PSC to maximize its effectiveness at night

Three-Dimensional Juvenile Salmon Behavior Associated with Fish Passage at Bonneville Dam Powerhouse I

Derrek Faber (USGS)*, Tom Carlson (PNNL), Mark Weiland (USACE-WES), Russell Moursund (PNNL), Noah Adams (USGS) and Dennis Rondorf (USGS)

Abstract

In the spring of 2000 we used a 3-D acoustic tracking system with micro-transmitters to determine the behavior of juvenile steelhead (*Oncorhynchus mykiss*) and yearling chinook (*Oncorhynchus tshawytscha)* as they approached and encountered fish bypass structures located at Bonneville Dam Powerhouse I. The 3D detection zone extended the length of Powerhouse I, and to 400 feet upstream of the forebay face of the dam. The objectives of this research were to: 1) Observe behavior of juvenile salmonids in 3D in relation to the Prototype Surface Collector (PSC), 2) Acquire passive movement data sets to test hypotheses associated with behavior of juvenile salmon in response to flow and dam operations, 3) Evaluate the premise that fish entry to the PSC is by chance alone, and 4) Estimate the proportion of ultrasonically tagged juvenile salmonids that meet the criteria for surface flow bypass entrance rejection (that is, an out-migrating fish has the opportunity to enter a surface collector opening but does not do so).

From April 25 to June 7, 2000 we released a total of 494 ultrasonically tagged juvenile salmon (331 steelhead and 163 yearling chinook) at mid-channel of the Columbia River at the Hood River Bridge. From this release location, all fish had equal opportunity to pass Bonneville Dam at the spillway, Powerhouse II or Powerhouse I and would have time to adjust to the river environment for normal behavior upon entry into the Bonneville Dam forebay. In the first 18 hours after each release we detected 42% of the juvenile steelhead and 19% of the yearling chinook released in the Powerhouse I hydrophone array. The travel times for juvenile steelhead and yearling chinook averaged 13.6 and 14 hours respectively.

We have *preliminary* results on 3-D tracks of 170 fish detected within the hydrophone array. We have determined the fate of 163 fish entering the forebay, of these fish:

- 116 exited on the south end of Powerhouse I (turbine units 1-6)

	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	South Sluice	Unknown
PSC	20	21	8	7	21	15	1	13
Under PSC	1	0	4	2	2	1		

- 40 exited on the north end of Powerhouse I (turbine units 7-10)
- 7 exited up-stream of array
- 7 fish have could not be 3D tracked

We also subjectively ranked 161 fish on their 3D track before they exited the forebay. Of the fish detected, 51 passed thru our array and the powerhouse quickly (< 2 hours), 37 searched for an exit (< 4 hours), and 73 showed a tendency to mill in the forebay (> 4 hours). The 3D tracks are currently being incorporated into a computational fluid dynamic (CFD) model to test hypotheses based on a juvenile salmon's response to flow.

Fish Position Estimation Error for the 3-D Acoustic Tracking Baseline Installed in the Bonneville I Forebay in the Spring of 2000

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Abstract

The error in position estimates for long-baseline tracking systems are known to depend on the following factors.

- The physical and acoustic environment,
  - The speed of sound, which varies with temperature, and
  - The acoustic noise background.
- The transmitting characteristics of the micro-transmitters, and the receiving characteristics of baseline hydrophones and receivers.
- Uncertainty in the locations of the hydrophones in the baseline array.
- The geometry and density of hydrophones in the baseline array.

We estimated the error in position estimates for micro-transmitters at fixed locations and others carried through the tracking baseline attached at a fixed depth to a GPS drogue. As expected, we found the error in transmitter position estimates to be continuously variable throughout the baseline. The magnitudes of 3-D position estimate errors were different for lateral and vertical components. Errors were typically less than 1m laterally but up to 30 m for estimates of vertical position. The maximum errors in vertical position were observed in locations where the geometry of the baseline was poor (hydrophones located very nearly in one plane) and where other problems, such as higher signal to noise, existed. Minimum errors in vertical position estimates, on the order of 1 to 3 meters, were obtained in the immediate vicinity of the PSC where the geometry of the baseline and signal to noise were good. Measurements of the speed of sound, taken in the operating environment of the tracking baseline, were found necessary to reduce the bias in position estimates.

Our experience has shown that careful attention must be given to the geometry and density of hydrophones in the tracking baseline in order to optimize the accuracy and precision of position estimates. It appears at this stage of our analysis that estimates of vertical position comparable to those we obtained for the lateral dimensions will require a higher density of hydrophones than our baseline and very careful attention to geometry. Continuous measurement of water temperature and the speed of sound in conjunction with very careful measurement of the location of hydrophones are also required to achieve high accuracy and precision (≤ 1m). The performance of the baseline, which includes any software used to extract time of arrival data and to estimate the 3-D position of transmitters, should be assessed frequently during a study period using GPS drogues and fixed location transmitters. It is important to be aware of and critically review the methods implemented in software that select the cluster of hydrophones to be used for each 3-D location estimate and any parameters that influence the performance of the numerical methods used to estimate transmitter position.

Field and Laboratory Studies in 2000 Regarding Guidelines for High Flow Smolt Bypass Outfalls

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abstract

High flow outfalls (> 1,000 cfs) are being planned or considered for inclusion at several dams in the Columbia River system, e.g., The Dalles and Bonneville dams. It is anticipated that these outfalls will be benign passage routes, with survival at least equivalent to or exceeding that realized at spillways, since the new high flow outfalls are being designed specifically for safe fish passage. However, current outfall criteria were developed for low flow outfalls (< 100 cfs), and may not always be applicable in a high flow situation. Thus, fundamental biological and hydraulic research is necessary to develop high flow outfall guidelines that ensure safe fish passage. The high flow outfall research we conducted in 2000 addressed these objectives:

- Entry conditions – (a) Determine the relationship between direct injury/mortality rate and the entry velocity of the outfall discharge jet at the surface of the receiving water; and (b) determine the time history of exposure to hydraulic conditions in the receiving water, e.g., energy dissipation, shear, and deceleration associated with various entry velocities and flows.
- Bottom impact -- Determine the relationship between water pressure at the bottom of the outfall pool and outfall discharge levels, jet trajectories, depth of fish travel in jet, and water depth. Relate these to field studies of injury/mortality.

Our general approach was to conduct field and laboratory studies and combine hydraulic and biological results into one comprehensive assessment. Field tests were conducted at the B2 sluice chute outfall (invert El. 29 ft during spring (June 12-18, 2000) and fall (September 28 to October 6, 2000). Two sluice flows were tested: 1,000 and ~2,500 cfs. During spring, "high" tailwater (range El. 15.9-22.1 ft, mean El. 19.0 ft) resulted in entry velocities of 30-40 fps. During fall, "low" tailwater (range El. 8.4-11.5 ft, mean 10.5 ft), resulted in entry velocities of 40-45 fps. Laboratory studies conducted at a flume tested entry velocities of 40-80 fps in 10 fps increments. Thus, the test conditions investigated in this study encompass discharge jet entry conditions expected at the new high flow sluice outfalls being designed for the Bonneville Second Powerhouse and The Dalles Dam.

Field Studies

Field studies included balloon-tag and sensor fish research. Balloon-tag mark-recapture techniques were used to estimate injury and survival rates for hatchery yearling spring chinook salmon. In all cases, treatment fish were released near the edge of the outfall jet. The intention was to expose them to the most hydraulically severe zone. During the spring, 750 balloon-tagged fish (500 treatment and 250 control) were released at the B2 sluice outlet. During the fall study, 1,040 tagged fish were released (693 treatment and 347 control). Injury rates were very low (1%). Preliminary survival rates (1 h and 48 h) from the balloon tag study for spring test were 0.996-1.004 and 1.004-1.008 for the 1,000 and 2,500 cfs conditions, respectively. Survival rates for the fall tests were 1.003-1.009 and 1.003-0.994 for the two sluice flows, respectively. Confidence intervals (90%) were less than ± 0.03.

Preliminary data from sensor fish releases during spring tests did not indicate bottom (El. –20 ft) impact, although the instrument was carried deep (~16 ft, to El. ~4 ft). This is in contrast to visual observation in the 1:30 model of the existing B2 sluice chute outfall that showed the 2,500 cfs jet impacting the bottom. Work is underway to understand this discrepancy and to characterize the time history of fish exposure to energy dissipation, shear, and deceleration associated with various entry velocities and flows during field and laboratory studies.

Laboratory Studies

Laboratory studies included hydraulic and biological research. The hydraulic studies took place at a 1:30 scale physical model of a high flow outfall. The objectives were to (a) characterize hydraulic conditions during the spring and fall field tests; and (b) physically characterize outfall jet dynamics at the bottom of the outfall pool. Field test characterization in the 1:30 scale model is still underway. Water pressure was measured in the 1:30 model for outfall unit discharges ranging from 67 to 467 cfs/ft of chute width and for a variety of plunge heights and tailwater depths for a flat river bed beneath the jet impact zone. This will be expressed as an equivalent impact velocity, which may permit either the selection of the necessary plunge height/tailwater depth ratio for a given outfall site, or the design of a plunge pool to prevent bottom impact of fish.
Biological laboratory research was conducted at a high velocity flume designed to simulate hydraulic conditions in the periphery of a high flow outfall jet. The objective of this research was to determine the relationship between injury/mortality rate and entry velocity. Two sets of fall chinook salmon were tested: (a) 150 fish of length ~100 mm; and (b) 160 fish of length ~150 mm. Individual fish were placed in an introduction chamber for the jet and ejected tail-first into a still body of water. Results for the smaller fish indicate that injury the lowest velocity studied with injury rates statistically significantly different than zero ($P<0.001$) was 60 fps. For the bigger fish, the lowest velocity with statistically significant level of injury ($P=0.002$) was70 fps. As entry velocity increased, mortality was first observed at 70 and 80 fps for the small and big fish, respectively.

Discussion

Biological tests focused on direct effects due to only jet entry. Worst-case conditions in the periphery of the outfall jet were studied, because this is where most of the energy dissipation occurs and, hence, is where fish are thought to be most vulnerable to direct injury during entry into the tailwater. By studying jet periphery, we maximized the chances of observing any injuries that might occur during high flow outfall plunge. This was a conservative approach to high flow outfall research because, for the jet as a whole, the periphery is a much smaller region for fish to be distributed in than is the main body of the jet. That is, assuming fish are uniformly distributed across a jet, generally most fish will be in the main body compared to the periphery.

Conclusion

Results to date indicate that the current 25 fps entry velocity criterion prescribed by NMFS can be exceeded in high flow outfalls. Based on field observations, high flow outfall entry velocities approaching 50 fps provide safe conditions for fish passage. Laboratory dose-response tests indicate that even higher entry velocities may be acceptable (up to 60 fps). Recommendations regarding the bottom impact guideline are still being formulated.

Application of a Three-Dimensional Computational Fluid Dynamics Model for the Bonneville Project

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Pacific Northwest National Laboratory (PNNL) applied a three-dimensional (3D) computational fluid dynamics model (CFD) to the Bonneville Project forebay for the US Army Corps of Engineers, Portland District. The model is being used to simulate the 3D velocity distributions near both powerhouses, including the turbine intakes and forebays, and the spillway channel. The hydraulic information from the CFD model is being used for the design of fish passage systems like the Prototype Surface Collector (PSC) and to investigate the potential linkages between project operations and adult migrant fallback.

CFD modeled velocities and turbulence quantities are being used in combination with hydroacoustic and radio telemetry fish tracking data to better understand how fish may be responding to the physical environment. Linking fish movement data with CFD provides an analysis tool to investigate many problems such as the possible causes of adult migrant fallback and ways to improve fish guidance systems.

A commercially available CFD code, STAR-CD, was used in this work. The model was applied to the region encompassing Powerhouse 1 and 2, the spillway channel, and a 2- and 1.2 km reach of the channel above Powerhouse 1 and Powerhouse 2, respectively. Engineering drawings for the powerhouses, PSC, fish guidance screens, and turbine intake extensions (TIEs), and recent bathymetric survey data were used to define the structural geometry and upstream channel bottom elevation. Grids were created using the commercial grid generation software packages GRIDGEN and ICEM-CFD and these data. Arc/Info geographic information system software was used to process bathymetry and shoreline data and the resultant bathymetric surface merged with the 2D channel grids to yield a 3D channel grid. The powerhouse grids were created so that simulations of different structural features such as the PSC and traveling screens could be done by

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activating thin-walls or “baffles”. Different operational conditions were simulated by specifying the total discharge outflow at each turbine and spillway bay.

The CFD model was verified using a variety of velocity data measured in the laboratory and in the field. For Powerhouse 1, a total of five types of datasets were used: velocities measured in a 1:25 scale sectional physical model, a 1:40 scale physical model, field-measured acoustic Doppler current profiler (ADCP), field-measured acoustic scintillation flow meter data, and field-measured acoustic Doppler velocimeter (ADV). At Powerhouse 2, 1:25 sectional data and a total of 4 sets of field-measured ADCP data were used in the verification. Agreement with the physical model data was quite good. Poorer agreement was obtained with field-measured velocities. This was due, in part, to the unsteady, turbulent nature of flow in the forebay as compared to the steady flow conditions simulated by the model.

CFD simulations for the PSC corresponding to operating conditions that occurred during the 2000 tests are being performed. The CFD model output is being delivered to the various biological research teams to allow them to overlay their respective fish tracking data with 3D velocity and turbulence fields. A set of TecPlot macros (TMV – Tecplot Model Viewer) was developed so that the research teams would have a common set of tools to query and analyze the CFD data.

The CFD model has also been used to investigate the potential hydraulic causes behind adult migrant fallback and to assess two alternative concepts for a structural solution to reduce fallback. Simulations for 12 operating conditions consisting of different combinations of Powerhouse 1 and Powerhouse 2 priority, and 2 levels of spillway flow. These simulations demonstrated that the upstream flow patterns, especially near the head of Bradford Island, are complex and sensitive to operating conditions. Two structural alternatives were simulated. These consisted of a wall and a curtain (the latter having a 10 ft bottom gap) located between the head of Bradford Island and the upstream emergent rocks. Whereas the alternatives were slightly different, their respective effect on the flow field was much different. These simulation results also highlighted the need to consider potential impacts on navigation when evaluating structural measures to reduce fallback.

The work to date has shown that the CFD model can reproduce the large-scale flow features near fish passage structures and upstream of the Bonneville Project. CFD provides an effective means of characterizing the 3D flows fields and investigating how fish movement may be correlated to these flow fields.

Evaluation of Smolt Movements Using an Active Fish Tracking Sonar at the Sluiceway Surface Bypass, The Dalles Dam, 2000

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abstract

Introduction –The Dalles Dam (TDA) sluiceway is an example of a successful surface flow bypass (SFB). It passes 20-50% of total fish passage at the powerhouse in only 1-5% of total powerhouse discharge. Since development of prototype SFB systems is well underway at many Columbia and Snake river dams, it would be useful to have a better understanding of what makes the TDA sluiceway relatively effective. The TDA sluiceway, however, is the only non-turbine passage route at the 22-unit powerhouse, so efforts are underway to improve sluiceway effectiveness. Turbine intake occlusion plates with "J-sections" are scheduled to be evaluated at TDA in 2001. The 2001 evaluation will be aided by baseline data on smolt movements at the existing sluiceway without turbine occlusion plates. Thus, the goal of the 2000 baseline study was to understand why the sluiceway is relatively effective. The objectives were to: (a) track smolt movements in the nearfield (<10 m) of the Sluice 1-1; (b) estimate state[5] probabilities; (c) estimate fate[6] probabilities; and (d) assess specific SFB premises about smolt movement in relation to the sluiceway.

Methods – Active fish tracking sonar (AFTS) was used to sample smolt movements in the nearfield of Sluice 1-1. AFTS is based on the principle of tracking radar. Once a smolt is detected with the digital split-beam hydroacoustic system, two high-speed stepper motors align the axis of the transducer on the target. As the target moves, deviation of the target from the beam axis is calculated and used to re-aim the transducer, thereby tracking the target. For each ping the target is tracked, three-dimensional fish position data are recorded. AFTS provided high resolution (~5 cm), fine-scale (<10 m), three-dimensional fish position data for the run-at-large. This population-level study had very high sampling intensity in the region of interest to produce detailed smolt movement data. About 100,000 smolts were tracked and about 5,000,000 positions located during the study from April 17 to July 7, 2000.

Results -- Descriptive data reveal that the database was composed of many relatively short tracks. More X, Y, Z positions were collected during night than day, even though more fish were tracked during day than night (average number of pings per tracked fish

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[5] A *state* is a fish movement pattern in the three dimensions (X, Y, Z). States are expressed as probabilities, i.e., the probability that a fish will be moving in a particular direction(s).

[6] A *fate* is where smolts exit the sample volume. Fates are expressed as probabilities of passage into a particular area, e.g., the sluiceway.

was 29 during day and 88 at night). Fish moved in positive and negative directions within the three-dimensions of the coordinate system. Ping-to-ping velocities were mostly –0.5 to 0.5 m/s. Mean target strength was higher during night (-43 dB) than day (-48 dB).

This baseline study of smolt movements in the nearfield (within 10 m) of Sluice 1-1 at TDA in 2000 revealed the following new information, as evidenced in the analysis of states, fates, and SFB premises:

- holding occurred in front of the upper portion of turbine intake entrances (where we sampled), but not the sluice entrances;
- smolts did not appear to avoid the sluice entrance;
- a zone of entrainment was indicated, but appeared to be relatively small (2-3 m from the dam);
- the zone of influence of the sluice flownet may be at least 10 m for the dam in the surface layer (0-3 m);
- attraction to the sluice flownet was indicated, although the response mechanism is unknown.

The study substantiated previous observations as follows:

- smolts moved from east to west through the nearfield and slow down in front of the sluice;
- smolts moved up in the water column to use a surface exit.

The TDA sluiceway is effective at bypassing smolts around turbines because, for the most part, the smolt population migrating through the powerhouse is: surface-oriented; concentrated at the west end of the powerhouse; perhaps using visual cues at the sluice weir; seemingly attracted to the sluice flownet; entrained in the sluice flownet; and, reluctant to sound, preferring a shallow passage route over a deep one.

We recommend that research at the TDA sluice in 2001 during J-occlusion tests address the following points:

- quantify and map hydraulic conditions in the forebay, including the nearfield of the sluiceway, with and without the J-occlusions;
- integrate observed smolt movement data with hydraulic data from a CFD;
- assess specific hypotheses about biological effects of smolt movements, such as: (a) the zone of influence of the sluiceway will be larger with J-occlusions than without; (b) the probability of moving upward and toward the sluice entrances will higher with J-occlusions than without; and (c) the probability of passage into the sluiceway will higher and more expansive in the forebay with J-occlusions than without.

FIXED-LOCATION HYDROACOUSTIC EVALUATION OF THE PROTOTYPE SURFACE BYPASS AND COLLECTOR AT LOWER GRANITE DAM IN 2000

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Abstract

In 2000, single-beam hydroacoustics was used to monitor fish passage at the surface bypass and collector (SBC), powerhouse, and spillway. A dual head multi-beam sonar was deployed to monitor fish movement in the vicinity of the BGS entrance. Two SBC entrance configurations were tested in 2000. These configurations are referred to as "Double" and "Single". Total SBC discharge for both configurations was 4,000 cfs. The Double configuration provided an opening, from the waters surface, of 19 ft at the Middle entrance and 21 ft at the BGS entrance. The Middle entrance was operated at a depth of 28 ft for the Single configuration. Two load levels, "High" and "Low", of Turbines 4 and 5 were incorporated into the study design to evaluate if SBC performance could be influenced by turbine load. Turbines 4 and 5 were each operated at approximately 13.6 and 17 kcfs for the Low and High load levels, respectively.

The BGS entrance to the SBC was also retrofit with special shaping within the SBC to allow for more gradual acceleration at the entrance and emulate a smooth crested weir. For comparison, the Middle entrance was unchanged and served as a sharp-crested weir surrogate. Flow was distributed evenly between the entrances and entrance velocities were approximately 6 to 7 feet per second (fps) and 7 to 8 fps for the BGS and Middle entrances, respectively for the Double configuration. Water velocity at the Middle entrance was approximately 9 to 10 fps while the SBC was in the Single configuration.

SBC efficiency relative to passage at Turbines 4 and 5 (R_{4-5}), the powerhouse (R_{1-6}) and overall (R_{all}) was significantly higher during the Single configuration ($P < 0.05$) (Table 1). Entrance efficiency (N) was also significantly higher during the Single configuration ($P < 0.05$). Entrance efficiency were 54 and 55% for the BGS entrance, and 58 and 57% for the Middle entrance during the Double configuration, under High and Low loads, respectively.

Table 1. Entrance efficiency (N) and SBC efficiency (%), during each configuration and turbine load, relative to the entire project (R_{all}), the powerhouse (R_{1-6}), and Turbines 4 and 5 (R_{4-5}).

Efficiency	Dbl/High	Dbl/Low	Sngl/High	Sngl/Low
N	57	56	72	71
R_{all}	41	42	47	45
R_{1-6}	53	53	59	57
R_{4-5}	59	62	65	64

During the Double/Low configuration, multi-beam monitoring upstream of the BGS entrance revealed that fish moved in mostly a south direction during day and night with the exception of the near region, closest to the entrance, during daytime when they moved equally in both directions. During the Double/High configuration, Fish near the structure continued to move toward the south during both day and night as did the fish in the middle range at night. During daytime, slightly more fish moved north in the middle region. During daytime, fish in the far region moved equally in both directions.

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PASSAGE SURVIVAL AND FISH CONDITION AT THE SURFACE BYPASS/COLLECTOR AT LOWER GRANITE DAM, 2000

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Abstract

The U. S. Army Corps of Engineers (Corps), Walla Walla District, Washington sponsored a study to estimate survival and condition of hatchery-reared chinook salmon, *Oncorhynchus tshawytscha*, (115 to 174 mm, average about 137 mm total length) in passage through the surface bypass collector (SBC) at Lower Granite Dam on the Snake River using the HI-Z Turb'N tag (balloon tag) recapture methodology. The Corps needed information on survival of fish passing through the SBC at a different entrance configuration and in channel hydraulic conditions than were obtained in 1996. Fish condition after passage via the SBC was previously obtained at a flow rate of about 3,400 cfs for fish introduced near the downstream end of the collection channel. The primary criteria set forth by the Corps for this study was to obtain estimates within a short time frame (less than two weeks) of both injury and survival of juvenile salmon passed through the SBC at a new entrance configuration and hydraulic conditions. The study was conducted using 403 fish from Little White Salmon National Hatchery on April 4 to 8, 2000. Survival probabilities at 1 h and 48 h were estimated for fish released in the SBC and Spillbay 2.

A total of 133 fish (primary treatment) was passed through the SBC. Because the fish diverted by the SBC pass downstream under a spillbay tainter gate (gate 1) an additional 130 fish (secondary treatment) were released through the Spillbay 2 tainter gate to separate its passage effects from those due to SBC passage effects. Some 140 control fish were released downstream of the discharge from Spillbay 1 to separate the effects of handling, tagging, and recapture from treatment passage effects.

The recapture rates for the treatment groups were 97.8 and 94.6%. The recapture rate for the control group was 92.1%; the lower recapture rate was primarily due to loss of fish to predation on 2 of 5 test days. It is possible that the dispersal of control fish upon exiting the induction hose was not consistent between the five release days. In contrast, the 1996 investigation conducted during the same time period in April revealed no predation loss; the control and Spillbay 2 fish recapture rates were 100% and the SBC fish recapture rate was 99.2%. However, in the 2000 study the recapture rates were sufficiently high to allow for quantifying the desired information from the allocated number of fish.

Adjusted for tailrace controls, the estimated 1 h and 48 h survival probabilities for the SBC fish were 1.06 (90% CI=1.01 to 1.11) and 1.05 (90% CI=1.00 to 1.10), respectively. The 1 h and 48 h survival probabilities for Spillbay 2 fish adjusted for tailrace controls were 1.03 (90% CI=0.98 to 1.09). Relative to Spillbay 2 fish, 1 h and 48 h survival probabilities for the SBC fish were 1.0 (90% CI=0.98 to 1.00) and 1.0 (90% CI=0.97 to 1.00).

However, a combination of survival probabilities greater than 1.0, known causes (predation) for non-recovery of the control fish (7.8%) with a relatively high degree of certainty, negligible loss of treatment fish to predation, and capture of dead or injured treatment fish prompted an alternative but realistic survival probability calculations. These calculations excluded predation-related losses from all of the three groups. The resulting 48 h survival probabilities are: SBC fish survival, adjusted for tailrace control, is 0.970 (90% CI=0.945 to 0.994); Spillbay 2 fish survival, adjusted for tailrace control, is 0.976 (90% CI=0.954 to 0.999); and SBC fish survival, relative to Spillbay 2 fish survival, is 0.994 (90% CI=0.957 to 1.00). These survival probabilities are slightly better than those obtained in 1996. The respective survival probabilities in 1996 were 0.958, 0.975 and 0.983.

Passage under the tainter gate and into the spill pool at Spillbays 1 and 2 appeared to inflict some injury (2.3 to 2.4%); however, passage into and through the SBC collection channel appeared to be benign. Primary injuries observed were hemorrhaged eye(s) and internal organ(s).

An Evaluation of Juvenile Chinook Salmon and Steelhead Passage through Lower Granite Dam relative to the 2000 Surface Bypass and Behavioral Guidance Structure Tests.

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Abstract

We used radio telemetry to evaluate the effectiveness of the behavioral guidance structure (BGS) and surface bypass collector (SBC) in attracting juvenile spring chinook salmon and steelhead during the spring of 2000. Tests conducted in 1996, 1997, and 1998 suggested that changes to the SBC entrances and turbine operations may improve the effectiveness of SBC. As a result, one of the openings to the SBC was modified to improve flow characteristics going into the SBC. In 2000, there were four treatments tested: 1) two SBC entrances open with high turbine operation (Double High), 2) two SBC entrances open with low turbine operation (Double Low), 3) one SBC entrance open with high turbine operation (Single High), and 4) one SBC entrance open with low operation (Single Low).

We surgically implanted radio tags in 935 hatchery spring chinook salmon, 485 hatchery steelhead, and 445 wild steelhead and released them into Lower Granite Reservoir. Results indicated differences in SBC performance between treatment tests. The proportions of fish that traveled within 6 m of the openings to the SBC were greater during the tests of double treatments (40-54%) than single treatments (31-44%). However, the number of fish entering the SBC (based on fish detected within 6 m) was greater for hatchery spring chinook salmon (85%; 34 of 40) and hatchery steelhead (46%; 13 of 28) during the test of a single low treatment. Wild steelhead entered the SBC at a higher efficiency during the test of a single high treatment (64%; 25 of 39).

We compared SBC performance results from 1998 to 2000. During 2000, the proportions of fish that discovered the SBC (fish detected within 6 m) were similar for hatchery steelhead (50% in 1998 to 49% in 2000), and increased by 4% for hatchery spring chinook salmon (36% in 1998 to 40% in 2000) and 14% for wild steelhead (32% in 1998 to 46% in 2000). Entrance efficiency (the number of fish to enter the SBC divided by the number of fish detected within 6 m of the SBC) increased 33% for hatchery spring chinook salmon (36% in 1998 to 69% in 2000) and 11% for wild steelhead (47% in 1998 to 58% in 2000). However, entrance efficiency decreased for hatchery steelhead from 63% (67 of 106) during 1998 to 39% (89 of 231) in 2000.

The BGS appeared effective at diverting fish away from the south half of the powerhouse (turbine intakes 1-3). Of the fish detected at Lower Granite Dam, 34% (292 of 869) of hatchery spring chinook salmon, 40% (189 of 476) of hatchery steelhead, and 36% (157 of 436) of wild steelhead were detected by underwater antennas within 10 m of the BGS. Of those fish, 29% (84 of 292) of hatchery spring chinook salmon, 28% (53 of 189) of hatchery steelhead, and 20% (32 of 157) of wild steelhead traveled under the BGS. In addition, 17% (49 of 292) of hatchery spring chinook salmon, 24% (46 of 189) of hatchery steelhead, and 21% (33 of 157) of wild steelhead traveled through the upstream gap. Of the fish that came within 10 m of the BGS, 54% (159 of 292) of hatchery spring chinook salmon, 48% (99 of 189) of hatchery steelhead, and 59% (92 of 157) of wild steelhead were diverted away from turbines 1-3.

Three-Dimensional Fish Tracking in Conjunction with the Operation of the Lower Granite Surface Bypass Collector and Behavioral Guidance Structure

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Abstract

The goals of our study were to observe the behavior of juvenile salmonids at high spatial resolution upstream of Lower Granite Dam and examine what stimuli migrants are responding to as they approach the surface bypass and collector (SBC). Our specific objectives were to evaluate fish behavior upstream of the SBC using a 3-D tracking system and integrate fish behavior data with water velocity information obtained from the CFD model. In previous years traditional fixed radio-telemetry and multibeam hydroacoustics have provided useful information on fish behavior upstream of the SBC. However, the high resolution information collected by the 3-D tracking system provided continous behavior data as juvenile salmonids approached and passed through Lower Granite Dam. In April and May 2000, we tagged and released 262 hatchery steelhead at Blyton Landing 18 km upstream of the dam. Overall detection rate (Total number released/number detected at least once) was 89%. Travel times and residence times were similar to those observed for radio-tagged fish Travel times from release to first detection ranged form 5 hrs to 207.5 hrs with a mean of 45.5 hrs. Residence times from first to last detection ranged from 1 hr to 191hrs. A large percentage of detected fish spent 1-4 hrs (median = 3 hrs) in the forebay. Three-Dimensional fish tracks were developed for 220 fish and 145 of these passed through the area upstream of the SBC. We calculated 2-d fish tracks >200 m upstream of the dam.

TESTING BEHAVIORAL TECHNOLOGIES IN CONJUNCTION WITH THE SURFACE BYPASS PROGRAM AT LOWER GRANITE DAM: DIRECTED FLOW EVALUATION

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abstract

Cowlitz Falls Dam (CFD) began operation in the spring of 1994 and was modeled after the Wells Hydroelectric Project on the Columbia River, Washington. A “state of the art” surface collector and facility, which included attraction, collection, dewatering, bypass, and handling/transport facilities, were completed in 1996. Results at CFD after three full seasons of operation and collection clearly demonstrated that many salmonid smolts did not readily find their way to the collection system, but passed the project through the turbines, either directly or by an induction slot. In 1999, we created large plumes of turbulence and increased water velocity in the forebay of CFD using submersible mixers (current inducers) and found we were able to alter the paths of radio-tagged juvenile coho salmon approaching the dam. A potential benefit of using current inducers to guide fish to surface bypass structures is to reduce the delay of juvenile salmonids that has been observed at mainstem dams. The delay has been associated with a back and forth movement that appears to characterize a search behavior for a surface passage route. It has been hypothesized that a “trail of turbulence” in the quiescent surface waters of a forebay would enhance the “opportunity for discovery” of the bypass entrance and minimize migration delay. In 2000 we used the current inducers to guide smolts to the surface bypass structure to increase fish guidance efficiency. The study design consisted of three test conditions 1) large-scale turbulent plumes, 2) small-scale turbulent plumes, and 3) an off condition. Each test condition was tested for 24 h and randomly arranged in 3-day blocks. We used 3-D acoustic telemetry, radio-telemetry, and flume sampling to determine the efficacy of the induced water currents as a guidance tool to increase fish collection efficiency of juvenile coho and chinook salmon at CFD. An acoustic Doppler current profiler (ADCP) was also used to quantify the effects of the current inducers on the hydraulic signature in the forebay. During the summer, we tagged and released 105 juvenile coho with acoustic tags and 328 juvenile chinook with radio tags. Preliminary results indicate that 41% of the tagged coho and 34% of the tagged chinook were collected in the fish collection flumes at the Cowlitz Falls Fish Facility. Preliminary flume sampling data indicated juvenile chinook responded to the flow patterns generated by the current inducers. Overall, 17% more juvenile chinook were collected with the large current inducers operating and 39% more juvenile chinook were collected with the small current inducers operating than during the off test condition.

TESTING BEHAVIORAL TECHNOLOGIES IN CONJUNCTION WITH THE SURFACE BYPASS PROGRAM AT LOWER GRANITE DAM: STROBE LIGHT EVALUATION

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abstract

Surface bypass of juvenile salmon has been studied at Lower Granite Dam, however we proposed to test strobe lights at Cowlitz Falls Dam (CFD) because of its relatively new design, small size, and similarity to Wells Dam. Cowlitz Falls Dam began operation in the spring of 1994 and was modeled after the Wells Hydroelectric Project on the Columbia River, Washington. A "state of the art" surface collector and fish facility that included attraction, collection, dewatering, bypass, and handling/transport facilities, were completed in 1996. During 1999, strobe light tests were conducted at CFD to determine if steelhead smolts could be deterred from entering the turbine induction slots thereby increasing the likelihood that they would encounter and enter the surface bypass collector. The 1999 study at CFD indicated the effect of the strobe lights was contrary to the expected result. Overall, 76% of the radio-tagged fish that passed through the induction slots did so through the lighted slot. The remaining 24% passed through the unlighted slot. In 2000 we re-examined the basic assumption that steelhead smolts will avoid strobe lights. Our objectives were to 1) determine the response of steelhead smolts to strobe lights positioned in horizontal and vertical positions near a net pen, and 2) determine the behavioral response of steelhead smolts to strobe lights at various turbidity levels. Strobe lights where installed around a net pen in the forebay of the CFD. We positioned the lights in two different configurations (vertical and horizontal) to determine the most effective position to elicit a response from steelhead smolts. We monitored the response of steelhead smolts to the operation of strobe lights using video cameras and depth sensitive radio telemetry tags. The net pen measured 1.5 m in diameter and 4 m in length and was positioned vertically in the water column. We conducted trials of both 3 min and 6 h to identify short and long-term reactions to the strobe lights. Preliminary results indicate juvenile steelhead exhibited an initial response to the strobe lights, with habituation occurring after initial exposure during both the 3 min and 6 h trials. If strobe lights can be successfully demonstrated, they could be useful at U.S. Army Corps of Engineers mainstem dams to enhance the efficiency of surface bypass/collection systems. At mainstem dams juvenile salmon approaching the surface collector often have downward trajectories that indicate entrainment and passage in water entering the turbines. A potential application is to place strobe lights below and upstream to encourage fish to avoid entrainment and approach the surface collector entrances.

Effects of Dam Passage on Juvenile Pacific Lamprey

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abstract

Since 1999, we have conducted studies to evaluate the swimming performance and behavior of juvenile Pacific lamprey (*Lampetra tridentata*) in the laboratory and the field. Initial studies were conducted on impingement rates using 1/8-in. bar screens, swimming performance, and effects of shear forces on juvenile lamprey. In 2000, we expanded our evaluation to include impingement rates using difference screening material, effect of angled screens, effect of light and pressure on migrating lamprey, and a field study to determine lamprey/screen interactions.

In the laboratory, a series of trials were conducted to evaluate the relationship between velocity and duration of exposure in juvenile lamprey impingement at time scales representative of a typical extended-length bar screen (ESBS) cleaning brush cycle period. These experiments showed that the longer lamprey stay on the screen and the higher the velocity, the more likely they are to become permanently wedged into the 1/8-in. bar screen. This generalization appears consistent for both experimental laboratory results and direct field observations. The 1/8" bar screen material currently used in ESBS is more likely to result in juvenile lamprey becoming permanently wedged into the bar spacing than 3/32-in. bar screen or 1/8-in. submerged traveling screen (STS) mesh. To further improve passage, we recommend the bars be oriented vertically, or in the direction of sweeping velocities.

Studies to determine the effect of light on eliciting avoidance responses were favorable. Juvenile lamprey tested in both static water and with a flow field showed a marked avoidance response and increased activity when subjected to high-intensity halogen and strobe lights. We also subjected lamprey to an abrupt pressure spike, which simulated turbine passage. We found no immediate or latent injuries as a result of this spike.

A field study conducted at McNary Dam using underwater video cameras showed lamprey partially impinged, that is, unable to lift themselves away from the screen face inside an operating intake. Lamprey were observed to begin tail-first penetration into the screens, but were able free themselves by volitional extraction of their tail from between the bar spacing. Sweeping velocities along the screen appeared to push the lamprey up the screen toward the gatewell.

Studies to date show that juvenile lamprey are not likely to be harmed by changes in pressure and shear conditions present during turbine passage. However, they are vulnerable to impingement on 1/8-in. ESBS bypass screens because of their weak swimming ability and tendency to use their tail to move on the structure. The size and shape of 1/8-in. STS and 3/32-in. bar screen precludes tail-first penetration behavior.

Determination of Passage of Juvenile Lamprey: Development of a Tagging Protocol

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abstract

Concerns over the decline of Columbia River pacific lamprey (*Lampetra tridentata*) led to the initiation in 1999 of a project to evaluate telemetry options to study juvenile lamprey passage around U.S.A.C.E. projects. In 2000, a component focusing on fungus control of captive lamprey was added to resolve problems associated with the long-term holding of juvenile lamprey in the laboratory.

Several telemetry options are available for use with lamprey, including PIT tags, radio transmitters, and visual marks. Each was evaluated, and in addition, harmonic radar, another promising technology, was investigated. Visual marks were determined to have limited use. Radio transmitters are the most desirable conventional option, as they allow for the long-range tracking of animals. Due to the small size of juvenile lamprey, however, implantation of these devices is severely restricted. Titley Electronics (Australia) produces the smallest available transmitter and several were obtained for experimentation. The Titley transmitter (approx. 400 mg) is still too large for implantation, primarily due to battery size. Initial attempts to attach these tags externally led to a severe impact on animal behavior. Further efforts to attach tags in other areas (mid-branchial area, fin rays), met with similar results. This transmitter will no longer be available due to quality control problems in production. Harmonic radar, which involves a passive diode tag, functions by using a transmitter to interrogate a tag with a radiowave pulse. The tag responds by re-broadcasting the signal at twice the originating frequency, and has been used to track animals as small as bees up to 800 meters away. Modeling radiowave transmission revealed that the maximum expected range for this technology would be on the order of 20 cm in water, making it little more effective than PIT tags. Custom battery production was investigated to determine if a smaller transmitter/battery unit could be created that would fit within the body cavity of a juvenile lamprey. Inquiries to multiple major manufacturers revealed that production of a battery of sufficiently small size was technically feasible, but that on the order of 10^6-10^7 units would need to be purchased in order to make it economically viable for the manufacturer.

At this time, the only viable monitoring option is PIT tags. The smallest PIT tags can be successfully implanted, and have a maximum range of 38 cm (Trovan Tags). The drawback is that the movement of these animals will only be characterized near PIT tag readers, not throughout the entire project. As battery technology improves and the production of high quality, miniaturized transmitter crystals becomes routine, radiotransmitters, rejected due to technical limitations, will need to be re-evaluated for use in these animals.

Juvenile lamprey are extremely susceptible to fungal infections when held long-term in laboratory facilities. Because of this an anti-fungal experiment was conducted. Four fungicides were evaluated during two different trials. Formalin, hydrogen peroxide, and a commercially available product (PX-700; Aquamedix, Florida) were tested at 12^{o} C and 22^{o} C during trial one, and salt (Instant Ocean) was evaluated at the same two temperatures during trial two. Each treatment was administered three times per week for four weeks. Formalin proved to be effective at both temperatures. Hydrogen peroxide was effective at the low temperature, but was acutely toxic at the warm temperature; resulting in 100% mortality within 24 hours. A lower dose of hydrogen peroxide was effective in controlling fungus at the warm temperature without the associated mortality. PX-700 was somewhat effective, but at a dose that would make it inefficient for large-scale use. Results from the salt treatment were equivocal, as there was very low overall mortality during the 28 days of the trial. At this time, two fungicides have been demonstrated to be effective for the treatment of fungus, which will facilitate the long-term care of experimental animals.

Evaluation of Delayed Mortality of Juvenile Salmonids in the Near Ocean Environment Following Passage through the Columbia River Hydrosystem

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The objective of our research is to determine whether barge transportation of salmonid smolts through the Columbia River hydropower system relative to in-river passage causes delayed mortality in the estuary and near-shore ocean. We will use acoustic telemetry to directly measure delayed mortality in the very early ocean, as well as through the lower river. In 2000 we went through a process to choose a vendor of remote-listening acoustic receivers, which will be used to account for fish passage through the lower river and into the ocean, and we designed the research in which this system will be used in 2001.

Although not linked to the design of the research, the choice of acoustic telemetry system (and therefore vendor) is intricately linked to our ability to carry out the research. To choose the best vendor for our needs and study area (i.e., Columbia River estuary and near-shore ocean), we had representatives of two vendors, Lotek and VEMCO, demonstrate their equipment to us in person in the Columbia River estuary and near-shore ocean in the summer of 2000. For each vendor, we tested their coded acoustic tag and receiver system in several locations throughout the estuary and near shore ocean in order to see the effects of salinity, noise (both from boats and surface wave action), and depth of water column on reception range. The acoustic systems were tested in calmer ocean conditions, rougher ocean conditions (between the jetties), several locations near the Astoria Bridge (freshwater to saltwater transition, with much boat activity), and upstream in a narrower part of the river (freshwater). At each location, we also tried to assess if there was any directionality associated with signal reception.

Each vendor's system was different. Lotek's system entails an acoustic receiver fixed in the water column, which turns the acoustic signal from the tag into a radio signal that is transmitted by a surface antenna to a radio receiver on land, where the data is recorded. VEMCO's system entails an acoustic receiver fixed in the water column which stores data internally. We feel that VEMCO's system is superior for our particular use for the following reasons:

- VEMCO tags are smaller (for use in smolts) and have many more available unique codes (note that the number of codes available are for *all* researchers in the system)

- although Lotek's receivers had a slightly greater range under calm conditions, VEMCO's receiver had noticeably better range under noisy conditions (boat and surface waves), which predominate in the estuary and near shore ocean during the smolt outmigration

- Lotek's radio receivers require upkeep during the course of the outmigration (~1x/week), while VEMCO's receivers can be placed once and then retrieved once, without any upkeep during the season

- the complexity of Lotek's datalogging system (multiple signal types and receivers and each acoustic receiver needing a surface buoy and antenna) make it more susceptible to user error, greater data processing time by the user, longer deployment and retrieval times, greater logistical demands, and damage in the extreme environment of the Columbia River

- deployment of Lotek's acoustic system is limited to approximately 8 km from land, hindering further future work farther out in the ocean

- both systems are susceptible to data loss

- cost of VEMCO's system is an order of magnitude lower than the Lotek system, making initial purchase and replacement of lost units much cheaper

Given the harsh and dangerous environment in which it will be used, the simplicity, performance, and cost of the VEMCO system make it superior to Lotek's. With this in mind, we designed arrays which will be used in 2001 research to monitor the passage of tagged hatchery steelhead smolts through the lower Columbia River and into the ocean. Three arrays will be placed in the system: one upriver at river kilometer (rkm) 89.3 where we have traditionally listened for radiotagged fish (making a nice comparison of the two telemetry systems because radiotelemetry by our group will be conducted concurrently with this research), one at the head of the lower estuary where the river widens (rkm 44.3), and one outside the jetties in the near shore ocean (rkm 0). The use of this system will, if all goes well in this environment, provide a first direct measure of delayed mortality and detection rates of tagged smolts in the near shore ocean. At a minimum we will be able to evaluate this fish accounting system.

Evaluation of the new Bonneville Dam Second Powerhouse Juvenile Bypass System

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abstract

In 1999, the U.S. Army Corps of Engineers completed a new juvenile bypass system (JBS) including a conveyance pipe and outfall downriver from Bonneville Dam Power House II. In 1999 and 2000, the U.S.G.S. evaluated the condition and behavior of juvenile chinook salmon (*Oncorhynchus tshawytscha*) and juvenile steelhead (*O. mykiss*) that passed through the new JBS. The objectives of our research were to determine: 1) the physiological effects on smolts traveling through the conveyance pipe, 2) the effects of passage through the conveyance pipe on tailrace egress behavior, and 3) how water velocities in the tailrace influence fish movements. We evaluated the stressful effects of passage through the new JBS by measuring plasma cortisol and lactate, and by examining passage and tailrace behavior using radio telemetry. Blood samples were obtained from fish that we released into the JBS and from river-run fish that entered the JBS under their own volition. In 1999, fish sampled at the downstream end of the JBS conveyance pipe showed higher cortisol and lactate levels than fish sampled prior to entering the pipe. We await the results of the physiology sampling conducted in 2000 to confirm these results. We used fixed antennas and mobile tracking to determine tailrace travel times and general movements of radio-tagged fish released into the JBS and upriver of Bonneville Dam. Radio-tagged fish exiting the JBS moved downriver and showed little sign of being consumed by predators or delaying in side channels. The 1999 physiology results indicated that passage through the bypass was stressful. However, radio tag data from 1999 and 2000 indicated that the increased level of stress did not significantly impact fish migration through the bypass and tailrace study area.

POST CONSTRUCTION EVALUATION OF THE JUVENILE FISH MONITORING FACILITIES AND CONVEYANCE PIPE AT THE BONNEVILLE DAM SECOND POWERHOUSE

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Abstract

Most components of the modified Bonneville Dam Second Powerhouse juvenile bypass system became operational during spring 1999. The permanent PIT-tag monitoring system and fish monitoring facility, however, were not completed at that time. To provide interim PIT-tag monitoring capability and to permit early identification of potential adverse affects to juvenile salmonids passing through the system, the National Marine Fisheries Service (NMFS) and U.S. Army Corps of Engineers installed temporary PIT-tag monitoring and fish handling equipment prior to the 1999 outmigration. During the first year of evaluation, NMFS released PIT-tagged yearling chinook salmon, steelhead, and subyearling chinook salmon into the bypass system to determine incidence of descaling, injury, and mortality, and to evaluate passage timing from the Second Powerhouse collection channel downstream to the Juvenile Fish Monitoring Facility (JFMF) site at Hamilton Island. Descaling, injury, and mortality rates observed for recaptured test fish were consistent with those expected for fish subjected to tagging and handling. There was little evidence of extended delay within the system; passage timing data indicated run-of-the-river fish moved through the system at rates approximating water particle travel time.

By spring 2000 the permanent PIT-tag detection and separation equipment and fish handling facilities at the JFMF were available. In the second year of our bypass system evaluation we determined detection and separation efficiencies of the new 134.2-kHz PIT-tag system, retention and physical condition of chinook salmon fry passing through the bypass system, and effects of system passage on physical condition of run-of-the-river yearling chinook salmon, sockeye salmon, and subyearling chinook salmon.

Detection and separation efficiencies of the PIT-tag system were evaluated using PIT-tagged hatchery-reared steehead and subyearling chinook salmon. About 600 fish of each species were released, typically one-by-one, into the JFMF sample flume just downstream from the Secondary Dewatering System (SDS). Overall (combined data for both species) detection efficiencies for the SbyC (Separate-by-Code) Separator Gate, River Exit, SbyC East Tank, and SbyC West Tank monitors were 100.0%, 99.2%, 99.8%, and 99.7%, respectively. The Sample/SbyC Exit monitor detected 91.2% of fish which were released from the recovery tank in batches of 100 to 200 fish and 100% of fish released one-by-one. The PIT-tag detection system also performed well during the spring and summer 2000 outmigration periods. Of 820 PIT-tagged, run-of-the-river yearling chinook salmon released into the bypass system for fish condition testing, 99.5% were detected at the SbyC Separator Gate monitor. Of 796 PIT-tagged, run-of-the-river subyearling chinook salmon released into the bypass system for fish condition testing, all were detected at the SbyC Separator Gate monitor.

PIT-tag separation efficiency of the SbyC Separator Gate was tested concurrently with detection efficiency, using the same fish as the efficiency tests outlined in the previous paragraph. MULTIMON was programmed so that fish were diverted into the East or West SbyC tanks or allowed to pass straight through at a ratio of about 1:1:1. For subyearling chinook salmon released at 800 and 1000 ms gate openings, 93.3% and 95.6%, respectively, went to the correct

destinations. For steelhead released at 800 and 1000 ms gate openings, all went to the correct destinations. During spring and summer fish condition tests, 99.4% of yearling chinook salmon and 98.6% of subyearling chinook salmon detected at the SbyC Separator Gate were diverted to the East SbyC Tank or into the Smolt Monitoring Program sample.

Upriver bright stock fall chinook salmon fry (average fork length 46 mm; range 38-51 mm) were used to determine retention within the system and condition following system passage. Average recovery percentages were 85.3% for live fry released into the collection channel at 11B and 84.1% for live fry released into the collection channel at the transition to the conveyance pipe. Equivalent recovery percentages for the two live fry releases indicated that fish were not being lost at the collection channel dewatering screens. Observations at the upstream switch gate (USG) indicated fish were being pulled under the gate by the head differential that existed between the sample and bypass sides of the gate. We examined a total of 639 recaptured fry from live release groups. There were no mortalities or visibile injuries resulting from system passage. None of the recaptured fry were descaled by "FTOT" criteria (>19% = "descaled"; 3-19% = "partial descaling"). Leakage at the USG has since been resolved by installation of a new gate seal.

We recaptured and examined 387 yearling chinook salmon released into the upper collection channel, 416 released at the SDS, and 292 released into the East SbyC Tank. As in 1999, injury and mortality rates were at background levels. By "FTOT" criteria, none of the 1,095 live fish recaptured were descaled in excess of 19%. We also determined descaling as a percentage of estimated total lateral surface area. By this method, none of the recaptured test fish were descaled in excess of 5%. Descaling ranging from 1% to 5% of lateral surface area was observed in 3.5% of fish released into the upper collection channel, 2.1% of fish released at the SDS, and 0.7% of fish released into the East SbyC Tank.

We recaptured and examined 389 subyearling chinook salmon released into the upper collection channel, 376 released at the SDS, and 367 released into the East SbyC Tank. Injury and mortality rates were again at background levels. Using "FTOT" criteria, four fish were descaled in excess of 19%, three from channel releases and one from an SDS release. Analysis of descaling as a percentage of estimated total lateral surface area showed descaling ranging from 1% to 5% of estimated total lateral surface area in 4.2% of fish released into the upper collection channel, 4.0% of fish released at the SDS, and 2.0% of fish released into the East SbyC Tank.

We conducted a pilot test to evaluate physical condition of sockeye salmon passing through the bypass system. This task included releases of PIT-tagged sockeye into the Second Powerhouse forebay (inner Boat Restricted Zone), gatewells 11B and 18B, and into the upper collection channel. Recapture rate for forebay-released sockeye salmon was 42%. Using "FTOT" criteria, we estimated that 1.0% of forebay releases, 4.7% of gatewell releases, and 1.0% of collection channel releases were descaled in excess of 19%. Higher observed descaling in gatewell- than forebay-released groups was unexpeceted, but could have resulted from small sample sizes (we recaptured and examined 210 and 261 fish from gatewell and forebay releases, respectively) or from non-representative conditions in gatewells chosen as release sites.

EVALUATION OF EXTENDED-LENGTH SUBMERSIBLE BAR SCREENS AT BONNEVILLE DAM FIRST POWERHOUSE, 2000

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Abstract

In the spring and early summer of 2000, we conducted research at Bonneville Dam First Powerhouse to determine levels of improvement in fish guidance efficiency (FGE), orifice passage efficiency (OPE), and levels of descaling and injury using three extended-length submersible bar screens (ESBSs) installed in turbine Unit 8. To further improve FGE by increasing flows into the gatewell, operating gates were raised in the A and C slots of turbine unit 8, and the gate was removed in the B slot to accommodate the fyke-net frame used for FGE testing. FGE and OPE were measured in Unit 8 and OPE was measured in Unit 9. OPE and fish condition between Unit 8 (with the ESBSs) and Unit 9 (with a standard Submersible Traveling Screen)(STS) were compared. Most of this testing added to results obtained in 1998 under similar conditions.

A total of 22 FGE tests were conducted from 24 April to 24 May, 2000. FGE for yearling chinook salmon averaged 66% (SE = 1.8). For both steelhead and coho salmon, mean FGE was 76%. For all three species, mean FGE in 2000 was 4 to 9% less than we observed in 1998. In 18 tests conducted from 12 June to 7 July, FGE for subyearling chinook salmon averaged 46 % (SE = 2.7). As seen in 1998 at Bonneville Dam First Powerhouse and at other projects, there was a steady decline in FGE for subyearling chinook salmon throughout the summer testing.

OPE tests were conducted using PIT-tagged fish which were released nightly (2200) into Unit 8 -A slot (ESBS and raised operating gate) and Unit 9 (STS and stored operating gate), then detected by the flat-plate detector in the downstream smolt monitoring facility. The percent OPE is the percent of these fish detected in 17 h (from 2200 to 1600) when the Unit 8 was shut down to facilitate preparing for the nightly FGE tests in the same units. In 11 tests conducted from April 25 to May 17, OPE for yearling chinook salmon averaged 76% (SE = 3.1) in Unit 8 (ESBS) and 73.3 % in Unit 9 (STS). The average time to detection was just over 4 h in Unit 8 and 3.5 h in Unit 9. During the summer tests, OPE for subyearling chinook salmon averaged 87% (SE = 1.8) in Unit 8and 89% 9(SE = 2.1) in Unit 9 with an average time to detection of 4.3 and 3.9 h in the two units respectively. For either species there was no significant difference in either OPE or time of detection between the two screen types.

To detect any increases in descaling or injury caused by the ESBS compared to the STS, samples of fish were collected for examination after the FGE tests had been conducted (both units on for 1.5 to 2 hours) and again the next day after the units had been operating for approximately 17 hours. During the spring tests, descaling for yearling chinook salmon, steelhead, and coho ranged from 6% to10% in Unit 8 and from 7% to 11% in Unit 9 with no significant differences between the two screen types. However, during summer testing, descaling in the ESBS unit (5.7% SE = 0.15) was significantly higher than the STS unit (4.2% SE = 0.98), P =0.049). For all four species

or life histories combined (spring and summer), injuries were less than 1% with no differences between screen types.

Based on a FGE averaged for the two years of testing, a ESBS with a raised operating gate at Bonneville Dam First Powerhouse can increase FGE by approximately 30% for yearling chinook salmon, steelhead, and coho salmon (based on 1991 STS results in Unit 8). The averaged FGE for all three species over the two years of testing a ESBS was 76%. During the early part of the summer migration, FGE for subyearling chinook salmon starts out averaging approximately 47% and averages close to 23% by the middle of July; however, this still amounts to increases in FGE. from 20 to 40% (based on averaged 1988 and 1989 STS results in Unit 3).

In 1998, descaling in the ESBS unit was significantly higher than the STS unit for yearling chinook salmon (10% to 8%, $P < 0.05$). However, there was no significant differences for any other species during the spring or summer migration. In 2000, descaling was significantly higher for subyearling chinook during the summer migration, only. In both cases the difference in descaling between the two screen types was approximately 2%.

Splitbeam Evaluation of Near-Field Fish Behavior at Bonneville Dam First Powerhouse, Unit 8.

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The fish guidance efficiency (FGE) of submerged traveling screens (STS) at Bonneville Dam's first powerhouse has been traditionally very low. Tests conducted in 1991 to estimate FGE yielded efficiencies ranging from 25% to 58% for spring migrating salmon and 4% to 11% for summer migrants. Extended–length submersible bar screens (ESBS) were installed and tested in 1998 with a marked improvement in FGE. Since 1998, a new design for the perforated plate behind the screen was developed to reduce vibrations that resulted in problems with plate attachment at other projects. This new design was deployed in the B-slot of Unit 8 of the Bonneville Dam first powerhouse and tests were conducted in 2000 to asses the effect on FGE performance. In concert with the FGE evaluation, fish behavior was monitored in the near-field to determine if the new design might alter approach conditions which would affect the FGE. The objective of our study in the spring/summer of 2000 was to characterize the near-field behavior of migrant juvenile fish upstream of the streamlined trash racks.

A multiplexed split-beam system was used to collect fish track data in the near-field of the trash racks at Unit 8 during the spring (May 4-June1) and summer (June1 to July15) sampling periods. Two 12 degree, stationary transducers were attached to the fifth section of the modified trash racks. These transducers were pointed up toward the surface. A single, down-looking transducer was deployed near the top of the trash rack and was mounted on a traversing system, which covered most of the slot width. Deployed on the traversing system with the transducer was a narrow footprint acoustic doppler current profiler (ADCP). The ADCP measured flow in the area sampled by the down-looking transducer. A total of 40, 578 files were collected in spring and summer by the splitbeam systems at Unit 8.

Despite increasing flows immediately upstream of the trash racks at Unit 8, fish appear to be deterministic in their behavior. Thus, while most fish were headed downward in the water column, they were equally likely to be headed upstream as downstream. Most fish were detected in the upper 10m of the water column and during the daytime hours. Few fish occurred below the toe of the ESBS, this may be related to delectability at this range due to excessive 200 kHz interference from the turbines. The fish that did encounter the newly designed trash racks had a higher daytime potential entrance efficiency than fish higher in the water column. While fewer fish were detected at night, they had a higher potential entrance efficiency than daytime fish. This suggests that visual cues may play a role in determining fish behavior in the near-field. Additional studies should investigate the ramifications of vision in determining fish behavior in the near-field.

Fish Guidance Efficiency of Extended-Length Submersible Bar Screens with Modified and Standard Perforated Plates

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abstract

Extended-length submersible intake screens (ESBS) are deployed at three U.S. Army Corps of Engineers, Walla Walla District (Corps) dams: McNary, Little Goose, and Lower Granite dam. These screens are approximately 40 ft long and have an upstream face of stainless steel bar screen, replacing screens that were approximately 20 ft long and had a rotating plastic mesh screen. The new, longer screens have resulted in increased fish guidance efficiency (FGE) over the old screens. Implementation of the new screen design occurred in 1996, 1997, and 1998 at McNary, Little Goose, and Lower Granite dams, respectively. Immediately after implementation of the ESBSs at McNary and Lower Granite Dam, failures were observed in the perforated plate bolt connection. In most cases, the plates bolted fasteners were missing and cracks in the stiffener plate welds were also observed. Analysis of the failed bolts confirmed that the failures were caused by fatigue as a result of vibration. Repairs associated with replacing bolts or entire perforated plate sections results in costly unit outages.

Engineering studies have determined that a full depth chamfer (30° chamfer measured from the hole axis) of upstream side of the holes in the plate virtually eliminates the vibration problem without an apparent change in porosity. However, there is some concern that changes to the perforated plate may cause fish to react differently to the screens possibly influencing FGE. Fish may sense the "noisy" screens some distance away and perhaps try to avoid that area. It is not known if this would increase or decrease FGE as the fish reaction to this vibration is unknown.

In 2000, we used single-beam fixed location hydroacoustics to monitor in-turbine fish passage and estimate FGE. A total of six screens were monitored, consisting of three ESBSs with the standard perforated plates and three ESBS equipped with perforated plates having full depth chamfered holes. One screen was deployed in the B slot of each turbine unit. Within the study design, adjacent turbines (Turbines 1 and 2, Turbines 3 and 4, and Turbines 5 and 6) were treated as pairs. A pair comprises an ESBS with standard perforated plates and an ESBS with modified perforated plates. Each screen was deployed in one of the two sampling locations within a pair, for one-half of the study period, to eliminate any potential location bias in FGE.

Our results demonstrated a strong treatment-by-location interaction. Fish guidance efficiency at Turbines 1 and 2 was significantly ($P < 0.05$) higher (3%) for the ESBS with standard perforated plates, unlike Turbines 3 and 4 where the FGE of the ESBS with modified perforated plates was significantly ($P < 0.05$) higher (8%). The treatment-by-location interaction suggests that FGE may be more a function of location rather than perforated plate type.

Prior to the study, regional biologists decided that if FGE of the ESBSs with modified plates was five percent or lower than that estimated for the standard plates, then the Corps should not proceed with replacing the existing perforated plates. A five percent decrease in FGE translates to a one-half of one percent decrease in powerhouse survival. Based on the results of the 2000 hydroacoustic evaluation, implementation of the modified perforated plate design will not result in a substantial decrease in powerhouse survival.

STUDIES TO IMPROVE WET SEPARATION AT FISH PASSAGE FACILITIES, 2000

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abstract

During the 2000 spring and summer juvenile salmonid outmigrations, research was carried out to provide refined biological design criteria for the improvement of McNary-style wet separators currently in use at fish passage facilities at hydroelectric dams on the Snake and Columbia Rivers. Using an evaluation McNary-style unit, six treatments compared the effects of lighting and smolt density on juvenile salmonid separation efficiency and orifice exit efficiency (OEE), and fish condition for river-run smolts exiting Gatewell 6B. Preliminary analysis of data from the spring outmigration indicated mean separation efficiency values ranging from 31 to 78% for all salmonids <180 mm, and 83 to 92% for smolts ³180 mm. During the summer outmigration, subyearling chinook salmon separation efficiency ranged from 57 to 91% using the evaluation separator. Total separation efficiency for all salmonid smolts was significantly higher using high light and medium light treatments than when the units were not lighted (low light) during both outmigration periods.

Results from evaluations completed over the last several years are intended as modifications to McNary-style separators. These modifications are proposed for comparison to existing conditions in the McNary operational separator during the 2001 outmigration. Based on the outcome of 2001 comparisons, modifications to existing McNary-style separator units can be considered for implementation.

Separation efficiency was also evaluated using two high velocity flume (HVF) separator units. Eight treatments involving standing wave height, water velocity, and flow angle in relation to the separation-bar array were compared using a prototype HVF separator at Ice Harbor Dam during the spring outmigration. Preliminary separation efficiency values ranged from 40 to 68% for smolts <180 mm, and 90 to 97% for fish ³180 mm. At McNary Dam an evaluation HVF separator was used to examine the effects of six combinations of light intensity and smolt density on separation efficiency and OEE. For the spring outmigration period, preliminary mean separation efficiency values ranged from 60 to 82% for fish <180 mm, and 76 to 85% for larger smolts. During the summer, subyearling chinook salmon separation efficiency ranged from 87 to 98% with the HVF separator. As with the McNary-style unit, total separation efficiency for all salmonid smolts was significantly higher using high light and medium light treatments than when the HVF was not lighted.

Adult separation is currently being evaluated relative to transport flows (3 m/s) and high HVF flows (2 m/s) using the prototype HVF at Ice Harbor Dam. The outcome of these tests will provide insight to efficient design and operation of a large fish and debris separator upstream from an operational juvenile salmonid separator.

EVALUATION OF SUB-YEARLING CHINOOK SALMON PASSAGE THROUGH THE McNARY DAM JUVENILE BYPASS SYSTEM

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Abstract

In 1999 and 2000 we conducted a BPA funded study to obtain survival estimates for subyearling chinook salmon through the bypass system at McNary Dam and to compare the survival of bypass system groups with fish released downstream from the dam. During the first year of the study, we found that fish were holding in the bypass system for up to 4 days. During the second year of the study, we released radio-tagged subyearling chinook along with the PIT-tagged fish in order to obtain additional information on this delay.

The objectives of this part of the study were to determine areas of delay for subyearling chinook and identify the causes for delay. Telemetry receivers monitored the orifice entrance to the collection channel, the collection channel exit, and the separator.

From 22 June to 20 July, we released 107 surgically radio-tagged subyearling chinook salmon into gatewell 8A at McNary Dam on the Columbia River. Median residence time in the gatewell was 2.8 hours, accounting for 96% of bypass delay. Median residence times in the collection channel and separator were 3.8 and 2.2 minutes, respectively. Median residence times in the bypass system for PIT-tagged fish and radio-tagged fish were 2.5 and 3.8 hours, respectively.

Evaluation of Migration and Survival of Juvenile Steelhead Following Transportation
and
Evaluation of Migration and Survival of Juvenile Fall Chinook Following Transportation

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The condition of juvenile salmonid migrants is affected by the structures and management procedures they encounter during migration; these effects influence the subsequent survival of the fish. This research is intended to provide information that will clarify the relationship between fish quality, as affected by structures and management, and migration behavior. With this information, it becomes possible to manage the migration of juvenile salmonids through the Columbia Basin hydropower system in such a way that later survival of migrants is maximized. Our goal is to make recommendations concerning how the fish transportation program may be managed to minimize the loss of fish in the Columbia River estuary.

Radiotelemetry (land-based fixed monitoring, boat tracking, and plane spotting) was used to monitor the migration and survival in the Columbia River estuary of barged and run-of-the-river (ROR) yearling steelhead and subyearling fall chinook released downstream of Bonneville Dam. Pressure-sensitive radiotags, in addition to normal radiotags, were used to document the depth at which yearling steelhead migrate in relation to water salinity, which may influence the vulnerability of migrants to some species of birds. Indices of stress, smoltification, and disease were measured for comparison to survival and migration behavior of radiotagged fish released on the same dates. The relationship between degree of smoltification and salinity preference of barged and ROR juvenile steelhead and fall chinook salmon was determined in the laboratory on several dates during the outmigration. These data were compared to behavior of radiotagged fish that traveled through the estuary and into saltwater to determine if developmental stage at the time the fish reach the estuary (a function of barging) affects survival, such that incompletely "smolted" fish will delay entering saltwater and thereby be more vulnerable to predators in the estuary. Finally, experiments were also completed on how feed intake and physiological adaptation to saltwater might be different between barged and ROR steelhead after saltwater entry. All results given below are still preliminary. For statistical significance, a=0.05 was employed.

Steelhead
A total of 143 steelhead were tagged, in four paired releases of barged and ROR fish. Following their release, steelhead in the lower Columbia River migrated 134-143 kilometers downstream to the fixed monitoring station (145 km downstream) in 31.9-89.9 hours. Mean swimming velocity was 3.3 kilometers per hour (kph) and ranged from 1.5-4.5 kph. There was no significant difference in migration speeds of barged and ROR steelhead in three of the four releases. There was a strong relationship between migration speed and river flow for the ROR fish ($p=0.0176$, $R^2 =0.9651$; linear regression). Large portions of both barged (70-90%) and ROR (40-100%) steelhead successfully migrated to the estuary. There was no significant difference between types in proportion of fish reaching the estuary. Migration patterns in the estuary were similar for barged and ROR fish. Large-scale patterns, as documented in boats and a plane, indicate that

fish travel very close to either the north channel (WA side) or the main shipping channel (OR side). Many also cross from the main to the north channel in the area upstream of the Astoria Bridge, which is a more direct path to the ocean. Upon reaching the lower estuary (river km 48), fish generally require two or three tidal cycles to reach saltwater. Movement of radiotagged juvenile steelhead in the lower estuary was influenced by the tide, with individuals moving downstream on an outgoing tide and holding or moving slightly upstream on an incoming tide. Depth tag data showed fish migrating in the top 4 m of the water column. Of all radiotagged steelhead, 5-25% of barged fish and 0-20% of ROR radiotagged fish, for the four different releases, were observed in colonies of piscivorous birds on Rice Island or East Sand Island. The proportion of fish found in bird colonies did not differ between barged and ROR fish. Out of all observations of both barged and ROR steelhead, the mean mortality was 9.8%.

There was not a significant difference in lengths of radiotagged barged and ROR fish in three of the four releases. Barged fish had a significantly higher condition factor than ROR fish on three releases. ROR fish had significantly higher levels of gill Na^+/K^+ ATPase than the barged fish on the first release only ($p=0.0385$; t-test). Prevalence of bacterial kidney disease was low throughout the season, with all of the fish having zero or low levels of infection; there were no differences in BKD levels between groups or through time. The saltwater preference experiments indicated that there were no significant differences in the percent of fish selecting saltwater for either type of fish, and fish did not choose saltwater preferentially. The feed intake experiment indicated that feed intake (% of body weight per feeding) did not differ significantly between barged and ROR fish on any given day. Fish in both groups appeared to be osmoregulating well, based on plasma sodium, plasma potassium, and muscle moisture levels. Only one mortality in both types of fish occurred during the 19 days of the feed intake experiment.

Fall Chinook

A total of 62 subyearling fall chinook were tagged, in two releases, though only one was a paired release of barged and ROR fish. An experiment was performed on the differences between gastric and surgical implantation of tags, which suggested that the surgical method produced less mortality immediately after surgery and 24 hours after the experiment in these small fish. Experimentation with antenna length of radiotags also indicated that fish with shorter antennas (15 cm vs 23 and 30.5 cm) survived and migrated. Following release, fall chinook in the lower Columbia River migrated 136-143 kilometers downstream to the fixed monitoring station in 37.2-66.1 hours. Mean swimming velocity was 2.9 kph and ranged from 2.2-3.7 kph. There was no significant difference in migration speeds of the barged and ROR fish in the only paired release. Movement of radiotagged juvenile fall chinook in the estuary was similar to that of steelhead. No radiotagged fish were observed in colonies of piscivorous birds in the lower estuary.

There was a significant difference in gill Na^+/K^+ ATPase levels between the two types of fall chinook ($p=0.0179$; t-test); ROR fish had higher levels of ATPase than barged fish. There was no significant difference in plasma cortisol levels between the two types of fish. Prevalence of bacterial kidney disease was low, with at least 88% of the fish tested having zero or low levels of infection. Saltwater fish in saltwater and that both barged and ROR fish had a strong preference for saltwater.

Estimates of fish and spill passage efficiency of radio-tagged juvenile steelhead and chinook salmon at John Day Dam, 2000.

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abstract

We estimated the fish passage efficiency (FPE) and spill passage efficiency (SPE) of two species of juvenile salmonids at John Day Dam to determine the effects of 12-h versus 24-h spill. The treatments were no daytime spill and 60% night spill (12-h spill) and 30% daytime spill and 60% nighttime spill (24-h spill). Results from hatchery-origin spring migrants in 2000 were similar to those from a similar study conducted in 1999. A total of 94% of the 971 radio-tagged spring migrants released 23 km above John Day Dam for this study were detected using automated telemetry equipment mounted at or near the dam. Fish guidance into the juvenile bypass system at the powerhouse during 12-h spill was similar to the proportion of fish passed via the spillway in the day during 24-h spill, resulting in no significant difference in FPE within either species between treatments. The FPE of yearling chinook salmon during 12 and 24-h spill were 84 and 90%. Those of juvenile steelhead were 93 and 88%. There were also no significant changes in SPE of steelhead between the two treatments, but yearling chinook salmon SPE was significantly higher during 24-h spill (83%) than during 12-h spill (66%). The median residence time of yearling chinook salmon in the forebay, within about 100 m of the dam, was reduced significantly during 24-h spill (4.5 h vs. 1.5 h). The overall median forebay residence times of juvenile steelhead were unchanged, but those smaller than 201 mm in fork length were affected in a manner similar to yearling chinook salmon, suggesting wild steelhead may be affected by day spill. Analyses of data from juvenile fall chinook salmon will be presented.

Monitoring tailrace egress in the stilling basin and at the bypass system outfall to determine differences that may lead to increases in predation or causal mechanisms of mortality at John Day Dam, 2000.

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Abstract

Radio telemetry was used to describe the movements and behavior of yearling and subyearling chinook salmon and yearling steelhead (*Oncorhynchus spp.*) to evaluate the spillway and juvenile bypass system as juvenile salmon passage routes. Test conditions were 60% spill at night and either 0% or 30% spill during the day, randomly assigned in three-day blocks. Fish were released from three locations along the spillway (north, middle south) and through the juvenile bypass system. Due to unanticipated river flows we were unable to assess the south spillway. Tailrace residence time was measured to a point 0.7 km downriver.

We released 144 yearling chinook salmon and 138 yearling steelhead during the spring migration. Residence time of bypass fish was not significantly different from spillway fish during 30% spill, but was significantly longer than spillway fish during 60% spill. Mean residence times during 30% spill ranged between 7.2 and 13.3 min for chinook and between 9.2 and 10.6 min for steelhead. During 60% spill, mean residence time of chinook released through the bypass (26.2 min) was more than twice as long as during 30% spill (10.2 min). The residence time of spillway fish was generally lower at 60% spill compared to 30% spill. Residence times of south and bypass chinook were significantly different between spill conditions.

During the summer migration we released 150 subyearling chinook salmon. The mean residence times of bypass fish were significantly longer than spillway fish, regardless of spill condition. There was no significant difference between the mean residence times of spillway fish during either spill condition, although north fish had the shortest residence times. During 60% spill, the mean residence time of bypass fish was more than five times longer than at 30% spill. Spillway fish had residence times that were generally lower at 60% compared to 30% spill.

Drogues were drifted through the tailrace to study the hydraulic conditions likely experienced by fish. We released 137 drogues during the spring and 103 drogues during the summer. In general, drogues released through the southernmost sites had significantly longer mean residence times. The mean residence times of drogues were generally shorter than the mean residence times of radio-tagged fish.

Spring 30% spill produced similar residence times, regardless of release site. At 60% spill, spillway fish had improved egress, and bypass fish were significantly delayed. Steelhead were less affected by the different spill regimes than were chinook salmon. During the summer, changes in the test conditions did not affect bypass fish, but their residence times were always higher than spillway fish. Our data suggest that changes in the spill regime can have dramatic effects on the egress of fish passing through the juvenile bypass system. These effects were most pronounced for yearling chinook salmon.

MONITORING OF TAILRACE EGRESS IN THE STILLING BASIN, THE ICE-TRASH SLUICEWAY AND THE POWERHOUSE OF THE DALLES DAM, 2000.

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abstract

Radio telemetry was used to examine the movements and behavior of yearling and subyearling chinook salmon (*Oncorhynchus tshawytscha*) in the tailrace of The Dalles Dam to evaluate the spillway, sluiceway and turbines as juvenile salmon passage routes. The test condition was a continuous 40% spill, juvenile pattern. Fish were released during the day and night to assess potential diel effects. Approximately even numbers of radio-tagged fish were released 200 m upriver of the north and south spillway, into main unit 1-1 of the sluiceway, a randomly assigned turbine unit, and at a reference location in the tailrace (controls). We measured tailrace residence time to the study site exit station (6 km downriver).

We released 375 yearling chinook salmon during the spring outmigration, approximately half during the day and half at night. The forebay residence time of north fish (32 min) was significantly longer than south fish (6 min) during both day and night releases. Spillway passage location was predominantly north for north fish (99%) and south fish (87%). The mean residence times of turbine fish (218 min) and sluiceway fish (189 min) were significantly higher than south (94 min), north (89 min), or control fish (77 min) during day releases. During night releases the mean residence times of turbine (179 min), south (157 min) and sluiceway fish (150 min) were significantly higher than north (108 min) or control fish (78 min). There were no significant diel effects for any release site.

During the summer outmigration we released 281 subyearling chinook salmon, 156 fish during the day and 125 fish at night. There was no significant difference between the mean forebay residence time of north (23 min) and south fish (11 min) during day or night releases. The north spillway was the passage location for 100% of the north fish and 81% of the south fish. During day releases, the mean residence time of turbine fish (343 min) was significantly higher than south (146 min), north (103 min), or control fish (81 min), but not significantly different from sluiceway fish (246 min). Turbine fish (404 min) had significantly higher mean residence times than sluiceway (238 min), south (197 min), control (132 min) or north fish (103 min) during night releases. There were no significant diel effects for any release site.

Drogues were drifted through the tailrace to study the hydraulic conditions likely experienced by fish. We released 59 drogues during the spring outmigration and 64 drogues during the summer outmigration. Drogues released through the north spillway had significantly lower residence times than drogues released through the south spillway. The mean residence times of drogues were not significantly different from the mean residence times of radio-tagged fish.

Control and north fish passed the exit station within approximately 1.5 h. During the spring outmigration, sluiceway and turbine fish passed the exit station in 2.5-3.5 h. During the summer outmigration, sluiceway fish took approximately 4 h to reach the exit station, and turbine fish took 5.7-6.7 h. The residence times of south fish were, in general, not significantly different from control fish. Tailrace egress was not significantly affected by the use of the study test condition during day or night periods.

MANAGEMENT OF CASPIAN TERN PREDATION ON JUVENILE SALMONIDS IN THE COLUMBIA RIVER ESTUARY.

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We initiated a field study in 1997 to assess the impacts of Caspian terns (*Sterna caspia*) on the survival of juvenile salmonids in the Columbia River estuary. Rice Island, a dredged material disposal island, supported an expanding population of about 16,000 nesting Caspian terns until 2000. This breeding colony was the largest of its kind ever recorded in the world, and supported about 75% of all the Caspian terns nesting along the Pacific Coast of North America. Diet analysis indicated that Caspian terns nesting on Rice Island consumed more juvenile salmonids than any other prey type (73% of prey items in 1998). Using bioenergetics modeling, we estimated that in 1998 Caspian terns nesting on Rice Island consumed about 10.2 million juvenile salmonids (95% confidence interval = 7.4 - 13.2 million), or approximately 11% (range = 8% - 14%) of the estimated 95 million out-migrating smolts that reached the estuary during the 1998 migration year. Analysis of over 36,000 smolt PIT tags recovered from the Caspian tern breeding colony on Rice Island revealed that steelhead smolts were more vulnerable to tern predation than other species of salmonids, and that over 13.5% of all PIT-tagged steelhead smolts that reached the estuary were consumed by terns nesting on Rice Island. Hatchery-raised yearling chinook salmon smolts were more vulnerable to tern predation than their wild counterparts. ESA-listed and unlisted salmonid smolts were consumed in proportion to their availability.

The magnitude of predation on juvenile salmonids by Rice Island terns led to management action in 1999. A pilot study was conducted to determine whether part of the Rice Island tern colony could be relocated 13 miles closer to the ocean on East Sand Island (rivermile 5), where it was hoped terns would consume fewer salmonids. Habitat restoration, social attraction (decoys and playback systems), and selective gull removal were used to encourage terns to nest on East Sand Island. About 1,400 pairs of Caspian terns nested at the new colony site on East Sand Island in 1999, where nesting success was good (ca. 1.2 young raised per nesting pair). The terns nesting on East Sand Island foraged more in marine and brackish water habitats than did the terns nesting on Rice Island, and the diet of East Sand Island terns consisted of 44% salmonids, or 41% fewer salmonids than were consumed by terns nesting on Rice Island. Despite the success of the pilot study, an estimated 11.8 million juvenile salmonids (95% confidence interval = 8.3 - 15.9 million) were consumed by Caspian terns in the Columbia River estuary in 1999.

The management plan in 2000 sought to prevent all nesting by Caspian terns on Rice Island and to attract all the terns that formerly nested at Rice Island to 4 acres of tern nesting habitat on East Sand Island. However, a court-ordered temporary restraining order precluded the elimination of all tern nesting on Rice Island. Nevertheless, 94% of the terns nesting in the estuary chose the colony site on East Sand Island. Tern nesting success at the East Sand Island colony was nearly four times higher than that at the Rice Island colony in 2000. Juvenile salmonids comprised 44% of the diet of terns nesting at East Sand Island, compared to 91% of the diet of terns nesting at Rice Island. The relocation of nearly all the nesting terns from Rice Island to East Sand Island resulted in a sharp drop in consumption of juvenile salmonids. Total consumption of juvenile salmonids by Caspian terns nesting in the Columbia River estuary in 2000 was estimated at 7.3 million (95% confidence interval = 5.7 - 9.3 million). This represents a reduction in smolt consumption by terns of about 4.4 million (38%) compared to the 1999 consumption estimate. Further reduction in the annual consumption of juvenile salmonids by Caspian terns in the Columbia River estuary will require restoration of tern colonies outside the estuary and the relocation of a portion of the East Sand Island colony to these alternative sites.

Hydroacoustic Evaluation of Fish Passage at The Dalles Dam in 2000

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We collected fixed-location hydroacoustic data on juvenile salmonid passage at The Dalles Dam in 2000. Our objectives were to estimate the proportion of smolts passing through the spillway, powerhouse, and sluiceway (fish passage efficiency). These estimates were also calculated per proportion of discharge (fish passage effectiveness). The results were described in terms of day/night and spring/summer for the May 13 to July 6 study period.

The acoustic screen model formed the basis for fish passage estimation; thus, single beam transducers were deployed across the project, and in addition one split beam transducer sampled at each type of deployment (spill, turbine, sluiceway). The split beam data were used for both detectability modeling and confirmation of fish entrainment through the sampled locations.

During the study, 66% of flow went through the turbines, 32% went through the spillway, and 2% went through the sluiceway. Only the juvenile, or nighttime, spill pattern was used and was not manipulated for the purposes of this study. Spill occurred 24 hr/dy throughout the study. During the spring block, species composition from the Smolt Monitoring Program at John Day Dam was 46% yearling chinook, 22% steelhead, 14% coho, and 13% subyearling chinook. During the summer block, 92% of the downstream migrants were subyearling chinook.

Preliminary results indicate that overall, day/night and spring/summer combined, total project fish passage efficiency was 0.89. Overall spill efficiency was 0.75, and spill effectiveness was 1.88. Overall sluice efficiency (in relation to the entire project) was 0.14 and effectiveness was 6.66. Overall sluice efficiency (in relation to the powerhouse only) was 0.59 and effectiveness was 16.7. Horizontal distributions showed passage was relatively uniform across the two-thirds of the spillway which was open, but peaked through the middle units of the powerhouse (Main Unit 5 to 15). Fish passage through the middle sluice gate (Sluice 1-2) was higher than the sluice gates at either side. Vertical distributions showed fish higher in water column at the spillway and sluiceway at night. The study results are reasonably consistent with those from previous studies.

Estimates of fish, spill and sluiceway passage efficiencies of radio-tagged juvenile steelhead and chinook salmon at The Dalles Dam, 2000.

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Abstract

We estimated the fish passage efficiency (FPE), spill passage efficiency (SPE) and sluiceway passage efficiency (SLPE) of two species of juvenile salmonids at The Dalles Dam during spring and summer 2000. The spill regime was a constant 40% spill passed via the juvenile spill pattern. The juvenile spill pattern places most spill discharge through the northern half of the spillway to avoid routing fish into areas of the tailrace known to harbor predators. Eighty-eight percent of the 1823 spring migrants released above The Dalles Dam for this and other studies were detected using automated telemetry equipment mounted on and near the dam. The median forebay residence times of juvenile steelhead and yearling chinook salmon were 0.8 and 0.6 h, respectively. The FPE, SPE, and SLPE of juvenile steelhead were 91, 85, and 6%, respectively. The corresponding estimates from yearling chinook salmon were 85, 82, and 6%. These estimates are nearer those resulting from 64% spill than from 30% spill during a similar study conducted in 1999. The SLPE estimates were considerably lower than previous estimates, but are likely due to differences in spill percent and pattern between years. Analyses of data from juvenile fall chinook salmon will be presented.

EVALUATION OF ICE HARBOR DAM SPILLWAY SURVIVAL

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Abstract

In recent years, spill has been utilized increasingly to expedite juvenile salmonid migration past hydroelectric dams and to reduce the proportion of smolts passing through turbines where survival is presumed lower. The current spill program, prescribed by the National Marine Fisheries Service 1998 Supplemental Biological Opinion, calls for up to 45 kcfs daytime spill and nighttime spill to the total dissolved gas saturation of 120% at Ice Harbor Dam. In 1999, estimated fish passage efficiency was 98% and spill efficiency was 83% for radio-tagged hatchery yearling chinook salmon passing Ice Harbor Dam under high spill volumes.

Survival estimates for juvenile chinook salmon that migrate through reservoirs, hydroelectric projects, and free-flowing sections of the Snake and Columbia Rivers are essential for developing effective strategies to recover depressed stocks. Study objectives for 2000 included using a paired-release model to estimate and compare relative spillway survival and migration rates to McNary Dam for river-run hatchery yearling chinook salmon (*Oncorhynchus tshawytscha*) using both PIT and radio-tag methodology, determine egress timing for radio-tagged fish through the Ice Harbor Dam tailrace, and estimate relative survival for PIT-tagged hatchery subyearling chinook salmon passing Ice Harbor Dam through the spillway. Fish were collected and tagged at Lower Monumental Dam and released at Ice Harbor Dam from 05 May to 07 July 2000. Treatment groups were released into the forebay directly in front of Spillbay 3, 5, or 7 while the reference groups were released into the tailrace about 0.5 km downstream from the stilling basin. Survival estimates were determined using detections of individual PIT-tagged fish at juvenile collection/detection facilities at McNary, John Day, and Bonneville Dams. The radio-tag portion of the study was postponed until 2001 because of transmitter malfunctions. Preliminary analysis indicates that relative spillway survival for hatchery yearling and subyearling chinook salmon was 0.978 (95% ci: 0.941, 1.018) and 0.885 (95% ci: 0.856, 0.915), respectively. Survival differences were not statistically significant between spillbays for either hatchery yearling (Range: 0.964 - 0.988, P = 0.896) or subyearling chinook salmon (Range: 0.858 - 0.927, P = 0.095).

RELATIVE SURVIVAL OF JUVENILE SALMON PASSING THROUGH THE SPILLWAY AT THE DALLES DAM, 2000

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abstract

In 2000, we continued research to determine the impact that spill at The Dalles Dam has on the survival of juvenile migrant salmon that pass the project. We PIT tagged approximately 45,555 coho salmon and 89,920 yearling chinook salmon for the spring portion of the test and 161,862 subyearling chinook salmon for the summer portion of the test. Detections of PIT-tagged fish were made at Bonneville Dam and the pair trawl study resulting in detection percentages of 20% for spring migrants and 3.5% of summer migrants. Results of detections made at avian rookeries are not yet complete.

In addition to a spillway release, groups of fish were released into the ice/trash sluiceway, turbine units and a reference group was released into the tailrace below the spillway. Spillway groups of fish were transported to the release location (approximately 200 m from the spillway) with a boat and released from 950-L tanks approximately 1 m from the water surface. We attempted to release equal numbers of fish at north and south spillway locations for each group. Tailrace groups were also transported to the release location with a boat and released approximately 1 m from the water surface. The release location near the proposed outfall site used in previous years was again utilized. Turbine groups were released across the powerhouse in both spring and summer test periods. These fish were released from 950-L tanks on the intake deck through a flexible hose into the turbine intake approximately 4 m below the intake ceiling. The flexible hose was held within a steel pipe and frame to maintain its position in the turbine intake. Immediately after the release of a turbine group a tank of water was released into the hose to flush any remaining fish from the hose. Groups of fish released into the ice/trash sluiceway were also released from 950-L tanks on the intake deck through a flexible hose. This hose was held in an adjustable steel frame to release fish at the surface of the water in the sluiceway. After fish were released this hose was also flushed with a tank of water to insure all fish had been removed from the hose. Marked groups of fish were released at these locations during the day and at night.

The spill level was held at 40% during the entire test period and the nighttime spill pattern was used 24 hours/day. The nighttime spill pattern concentrates spill on the north side of the spillway. Preliminary results of spring 2000 testing indicates relative survival (with 95% confidence intervals) of 95% (92 - 99%) for spillway releases, 95% (92 - 98%) for sluiceway releases, and 81% (78 - 84%) for turbine releases. Preliminary results of summer 2000 testing indicates relative survival of (with 95% confidence intervals) 92% (83 - 101%) for spillway releases, 96 (88 - 104%) for sluiceway releases, and 84 (76 - 92%) for turbine releases. Statistically significant survival differences related to diel period were not noted for any of the release locations for either spring or summer test periods.

In 1997, we found that at a 64% level of spill, relative survival (with 95% confidence intervals) of coho and subyearling chinook salmon that passed through spill compared to reference groups released downstream of the tailrace was 87% (80 - 94%) and 92% (86 - 99%), respectively. The number of fish tagged for the study (about 43,000 coho salmon and about 53,000 subyearling chinook salmon) was insufficient to detect significant differences related to other factors such as spill pattern, location of passage through the spillway, spill gate opening, or flow volumes.

In 1998, we measured levels of survival for fish that passed through a 30% and 64% level of spill, and through the sluiceway at 30% spill (daytime spill pattern). We tagged about 64,000 coho salmon and 80,000 subyearling chinook salmon for the study. Results indicate that 13% of the coho salmon and 5.3% of the subyearling chinook salmon released as reference fish were detected passing Bonneville Dam. During spring tests we derived the following relative survival estimates for coho salmon: sluiceway passage -- 96% (87-105%); spillway passage at 30% spill -- 97% (88-107%); and spillway passage at 64% spill -- 89% (82-95%). During summer tests we derived the following relative survival estimates for subyearling chinook salmon: sluiceway passage -- 89% (81-97%); spillway passage at 30% spill -- 89% (80-99%); and spillway passage at 64% spill -- 75% (68-83%).

In 1999, we repeated the 1998 tests with increased precision, but excluding the sluiceway measurements. We tagged 22,165 coho salmon and 116,911 chinook salmon for the spring portion of the study, and 166,727 subyearling chinook for the summer portion. Spillway test fish were released at three locations about 200 m upstream from the dam centered in the north, middle, and south thirds of the spillway. Results for 1999 tests, indicate that 17.2% of spring migrants and 12.5% of the summer migrants released as reference fish were detected passing Bonneville Dam. During spring tests, the relative survival estimates were as follows: spillway passage at 30% spill -- 95% (91-98%); and spillway passage at 64% spill -- 94% (90-97%). During summer tests, the relative survival estimates for subyearling chinook salmon were as follows: spillway passage at 30% spill -- 100% (96-104%); and spillway passage at 64% spill -- 96% (92-100%). Also, test fish released at night with spill patterns that minimized flow through the south bays had a significantly higher survival than test fish released during the day.

Multi-year survival trends for 1997 - 99 within spring and summer migrant survival data were not evident for changes of date, river flow, spill, tailwater elevation, or temperature. However, nighttime releases were significantly different (higher) than daytime releases. In 2 of 3 years passage survival was poor at 64% spill. Estimated passage survival at 30% spill was equivalent to or better than at 64% spill in all tests.

Analysis of 2000 data for survival trends relative to date, river flow, spill, tailwater elevation, or temperature have not been completed at this time.

Estimate the Survival of migrant Juvenile Salmonids in the Columbia River from John Day Dam through Bonneville Dam using Radio-Telemetry

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abstract

Abstract--Assessing the survival of juvenile salmonids through hydroelectric projects and reservoirs in the Columbia River Basin will help identify strategies that can be used to recover depressed stocks. To assess the survival of migrant juvenile salmonids, passive integrated transponder (PIT) tags have been used in conjunction with mark-recapture models to generate survival estimates. Recently there has been interest in examining the feasibility of using radio-tagged fish to complement current PIT tag survival studies and to provide estimates of survival in reaches where the detection capabilities of PIT tags are limited. Results from a study conducted by the USGS at the John Day Dam during 1999 suggested that using radio-tagged fish to estimate survival was feasible and that modifications to the release protocols used during 1999 would further satisfy the assumptions of the mark-recapture models. The goal of this study was to use releases of radio-tagged fish for studies examining juvenile salmonid passage at the John Day, The Dalles, and Bonneville dams to generate survival estimates for yearling chinook salmon and steelhead trout at John Day Dam, generate survival estimates of yearling and sub-yearling chinook salmon at The Dalles Dam for comparisons with estimates generated using PIT-tags, and to evaluate the logistics associated with using radio-tagged juvenile salmonids to generate survival estimates at Bonneville Dam.

Hydroacoustic Evaluation of Fish Passage Through Bonneville Dam in 2000

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Abstract

Objectives and Methods – The objectives of this fixed-aspect hydroacoustic study were to: 1) produce the first estimates of fish passage efficiency (FPE) for the entire Bonneville Dam project for both spring and summer; 2) produce FPE estimates for the three main component structures (Powerhouses 1 and 2 and the spillway) at Bonneville Dam in both passage seasons; 3) estimate other fish-passage metrics including FGE and fish guidance effectiveness by turbine unit; 4) compare passage metrics by fish protection structure type including the Prototype Surface Collector (PSC) on Units 1-6, Submerged Traveling Screens (STS's) on Units 7, 9, and 10, and an Extended Submerged Bar Screen (ESBS) on Unit 8; 5) characterize horizontal, vertical, daily, and seasonal aspects of fish passage at all dam structures; and 6) determine the vertical distribution of fish approaching the dam at two locations upstream of Units 12 and 14 at Powerhouse 2. We report results of most of those efforts here.

Sampling was around the clock with a short break each morning for data downloading and archiving and employed 70 separate fixed-aspect 420 kHz hydroacoustic transducers. We sampled all intakes of Turbine Units 1-6, one intake each of Turbine Units 7-10, 11 of 16 operational spill bays, and one intake each of Turbine Units 11-18. At Units 1-6 (the PSC) and at the spillway all transducers were down looking (the in-turbine beams downstream of the PSC were divided into "guided' and "unguided" range bins) whereas all of the other deployments were opposed pairs of up looking ("guided") and down looking ("unguided") deployments. Although most deployments used single-beam transducers, at least one split-beam transducer or split-beam pair was used at each kind of deployment (except for the down looking single-beam transducers downstream of the PSC at Units 1-6) to provide deployment-specific data on fish speeds, trajectories, and target strengths for detectability modeling. Five of the 6 PSC intakes (Unit 3 was involved in a separate PNNL study), also were sampled with opposed pairs of split-beam transducers just upstream of the openings to obtain trajectories for entrance efficiency estimates.

Passage estimates were made from spatial and temporal expansions of counts from automated hydroacoustic tracking software. A subset of the raw data also was processed by trained technicians to provide a quality control check on the automated processing software.

Spring Results

Metric Estimates- We estimated Project FPE (the ratio of the number of fish passing by all non-turbine routes to the total number of fish passing the project) to be 0.81. Fish passage efficiency was 0.67 at Powerhouse 1 and 0.54 at at Powerhouse 2. Spill Efficiency (the ratio of estimated spillway passage to estimated total project passage) was 0.49. At Powerhouse 1, both the PSC (Units 1-6) and Unit 8 (ESBS) had FGE's of

0.72. . Powerhouse 1 units with STS's (Units 7, 9, and 10) had an estimated mean FGE of 0.48. All Turbine Units on Powerhouse 2 employ STS's and had an estimated mean FGE of 0.73 in spring. We estimated spring Spill Effectiveness (spill efficiency times the ratio of total project water volume passed to water volume spilled) to be 1.51, which was significantly lower than the effectiveness of PSC slots at Powerhouse 1. We estimated the effectiveness of the PSC to be 2.15.

Vertical Distribution of Fish Approaching the Dam Upstream of Units 12 and 14

Two up looking bottom-mounted transducers sampled fish approaching Powerhouse 2's intakes 14c and 17b. At both sites almost 100% of the fish detected 100 ft upstream from the face of the dam were above the elevation of the top of the intake (EL 39 ft).

Horizontal Passage Distribution

In spring, 34 % of an estimated 49.4 M juvenile fish passing the Bonneville Project passed at Powerhouse 1 and 45 % passed at the spillway. These percentages were significantly higher than the percentage passing Powerhouse 2 (20 %) which would not have been expected given the distribution of flow (Powerhouse 1 = 32; Spill = 32; and Powerhouse 2 = 35 %. At Powerhouse 1, 28 % of fish passage occurred at Units 7-9 (Unit 10 was down most of spring) and 72 % occurred at PSC Units 1-6. At the spillway, more fish and more fish per M m^3 of water passed at bays 2-4 and 8-14 than through 5-7 and 15-17. At Powerhouse 2, fish passage was higher at units 13 and 15 than at units 17 and 18, but all other estimates had overlapping 95 % confidence intervals.

<u>Summer Results</u>

Metric Estimates- We estimated Project FPE to be 0.82. Estimated FPE at Powerhouse 1 was 0.61; FPE at Powerhouse 2 was 0.35 and spill efficiency was 57 %. These results should be tempered with the fact that most units at Powerhouse 2 did not operate most of the time in summer. At Powerhouse 1 the PSC had, as in spring, an estimated FGE of 0.72. Powerhouse 1 units with STS's (Units 7, 9, and 10) had an estimated mean FGE of 0.36. All Turbine Units on Powerhouse 2 employ STS's and had an estimated mean FGE of 0.35. Estimated FGE at the ESBS at Unit 8 (PH 1) was lower in summer (0.50) than in spring (0.72). FPE increased during the 30 days for which we report data.. We estimated summer Spill Effectiveness to be 1.19 and PSC effectiveness to be 2.24.

Horizontal Passage Distribution

In summer, 41 % of an estimated 34.6 M juvenile fish passing the Bonneville Project passed Powerhouse 1 and 52 % passed at the spillway. Only 7 % of the fish passing the Project passed at Powerhouse 2. The distribution of fish passage was more similar to that of flow among the structures in summer than it was in spring. About 42 % of flow passed at Powerhouse 1, 48 % passed at the spillway, and 10 % passed at Powerhouse 2. About 69 % of 14.3 M fish passed through PSC units at Powerhouse 1 while 31% passed at Units 7, 9, and 10, and 4.9 % passed at Unit 8. The distribution of passage of fish at the spillway in summer was similar to that observed in the spring. At Powerhouse 2, 79 % of fish and flow passed through units 11, 17, and 18. Although 24.7 % of flow passed through Unit 17, only about 2 % of the fish passed there. FGE was lowest (7 %) at Unit 11 and was 31 and 49 % at units 17 and 18, respectively.

<u>Vertical distribution of fish approaching the dam at upstream of Units 12 and 14</u>

Two up looking bottom-mounted transducers sampled vertical distributions of fish approaching Powerhouse 2's intakes 14c and 17b. At both sites almost 100% of the fish detected 100 ft. upstream from the face of the dam were above the elevation of the top of the intake (EL 39 ft). Immediately upstream of intake 14c, 68% of all fish detected were above the top of the intake opening and 88% were above the tip of the STS. Immediately upstream of intake 17b, 82% of all fish detected were above the top of the intake opening and 96% were above the tip of the STS. According to our examination of fish distributions and flow lines, FGE would be 94% if vertical distribution and flow pattern were the sole determinants of fish guidance. However, the estimated FGE for Unit 17 was only about 31 % in summer.

Hydroacoustic Evaluation of Fish Passage at John Day Dam in 2000

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abstract

We collected fixed-location hydroacoustic data on juvenile salmonid passage at John Day Dam in 2000. Our objectives were to estimate the proportion of smolts passing through the spillway and powerhouse (fish passage efficiency). These estimates were also calculated per proportion of discharge (fish passage effectiveness). The results were described in terms of day/night and spill treatment for the June 6 to July 6 study period.

The acoustic screen model formed the basis for fish passage estimation; thus, single beam transducers were deployed across the project, with one split beam transducer sampled at each type of deployment (spill, powerhouse). The split beam data were used for both detectability modeling and confirmation of fish entrainment through the sampled locations.

During the study, spillway flow was manipulated between 0% and 30% during the day and maintained at 60% spill during night. Each spill treatments was assigned to either the first or last 3 days of a 6-day block. Dam operations were effective in implementing the spill treatment schedule. The following analyses are based on 24-hr periods of each spill treatment. During this study, the species composition from the Smolt Monitoring Program at John Day Dam was 92% subyearling chinook.

Preliminary results indicate that fish passage efficiency was significantly greater ($p<0.05$) for the 30% spill treatment than for the 0% spill treatment. The magnitude of treatment differences in spill efficiency differed among blocks, but the direction of difference was consistent across all blocks. Spill effectiveness was significantly lower ($p<0.05$) for the 30% treatment than for the 0% spill treatment. Fish per unit discharge in spill did not differ significantly among treatments.

Horizontal distribution of fish passage at the spillway clearly reflected the 30 versus 0% spill, with less differentiation between day and night. Day/night differences dominate the horizontal distribution of fish passage at the powerhouse, with less differentiation among 30 and 0% spill treatments. Diel patterns of fish passage differ among 30 and 0% spill treatments at the spillway, but also at the powerhouse. A higher peak of fish passing during midday is evident during the 0% spill treatment.

EVALUATION OF JUVENILE SALMONID TRANSPORTATION, 2000

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abstract

In 2000, we continued to research the potential benefits of transportation to increase survival of juvenile salmonids. We conducted the fifth year of yearling chinook salmon smolt marking and the second year of steelhead smolt marking to evaluate inriver migration vs. transportation of smolts PIT-tagged at Lower Granite Dam. We also recovered adult spring/summer chinook salmon PIT-tagged as smolts in 1998 and 1999 and adult steelhead PIT-tagged as smolts in 1999.

Two major changes in study protocol occurred in 2000; we marked only wild fish and we released all tagged fish into the Lower Granite Dam tailrace. The transport group was comprised of smolts collected and transported from Little Goose Dam. The inriver group will be comprised of those smolts that were not detected at a Snake River collection dam below Lower Granite Dam.

From 30 March to 19 June 2000, we PIT tagged 59,333 wild yearling chinook salmon and 71,107 wild steelhead smolts. Post-marking delayed mortality (24 hour) averaged 0.8% for wild yearling chinook salmon and 0.2% for wild steelhead during the period. At Little Goose Dam, 15,521 wild yearling chinook salmon and 21,786 wild steelhead smolts were transported. After all of the collection facilities are closed for the year, we will determine the fish that will comprise the inriver groups. Calculations of transport-to-inriver-migrant adult return ratios (T/I) will be made when adult returns are complete in summer 2003.

From the 1998 juvenile releases, through 28 September, we recovered a total of 223 (197 hatchery and 26 wild) transported fish and 115 (89 hatchery and 26 wild) inriver fish that were not detected at a Snake River dam below Lower Granite Dam. The T/I for hatchery fish was 1.2, while the T/I for wild fish was 0.6. We recovered jack spring/summer chinook salmon PIT-tagged in 1999. Through 28 September, we recovered 88 (77 hatchery and 11 wild) transported and 22 (21 hatchery and 1 wild) inriver fish that were not detected at a Snake River dam below Lower Granite Dam. For steelhead, through 15 October, we recovered a total of 179 (151 hatchery and 28 wild) transported fish and 40 (all hatchery) inriver fish that were not detected at a Snake River dam below Lower Granite Dam. The T/I for hatchery fish was 1.0. With no wild inriver returns to date, we cannot calculate a T/I for wild fish at this time.

ESTUARINE DETECTION OF PIT-TAGGED JUVENILE SALMONIDS USING A PAIR-TRAWL, 2000

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abstract

A new International Standards Organization (ISO) 132 KHz PIT-tag detection system was operated in the exit of a pair-trawl for 553 hours in the Columbia River estuary at Jones Beach, river kilometer 75, between 18 April and 21 June 2000; 5,940 PIT-tagged fish were recorded. The new detection system included improved electronics, software, and an underwater antenna having a single 91-cm diameter opening. Volitional fish passage through the larger antenna opening was markedly improved compared to 1999 using a 400 KHz detection system when the antenna system consisted of a single 46-cm diameter opening.

Sampling effort increased from 8 hours per day to 16 hours per day on 2 May coincident with the arrival in the estuary of inriver migrants from the Lower Granite Dam transportation study; the exception was on Mondays when an 8 hour sampling effort occurred. Between 5 June and 21 June we reduced sampling effort to 8 hours 3 to 5 days per week targeting subyearling chinook salmon (102 detections). During the 16 hour daily sampling period we averaged 1.4, 0.9, and 2.1% detection of yearling chinook salmon, coho salmon, and steelhead respectively, previously detected at Bonneville Dam–a rough measure of sampling efficiency. There was a significant difference in detection rate at Jones Beach for yearling chinook salmon released at The Dalles Dam and detected at Bonneville Dam compared to those released at Lower Granite Dam and detected at Bonneville Dam (0.8 and 2.3%, respectively, $P<0.05$). The lower detection rate for The Dalles fish may be related to timing differences in passage at Bonneville Dam.

We detected 1,450 PIT-tagged fish from the transportation study released for inriver migration from Lower Granite Dam; 565 yearling chinook salmon and 885 steelhead. Of these, 118 yearling chinook salmon and 221 steelhead had been diverted to barges at Little Goose Dam and transported to downstream from Bonneville Dam for release. As in previous years, we speculate that a longer more uniform period of availability for inriver migrating fish released at Lower Granite Dam probably accounted for the increased number of detections for these fish compared to transported fish. This was the second year that steelhead were PIT-tagged for transport evaluation and the fourth year for chinook salmon. Nearly all of the transportation study fish PIT-tagged in 2000 were naturally produced and their subsequent detection in the estuary provide a valuable comparison to earlier years which emphasized primarily hatchery fish.

Travel speed for PIT-tagged fish detected at Bonneville Dam (inriver migrants) was significantly faster to Jones Beach than for PIT-tagged fish released from transportation barges for chinook salmon (88.7 and 81.1 km/day, respectively, $P=0.01$) but not for steelhead (90.8 and 87.4 km/day, respectively, $P=0.30$). Additional timing and travel speed comparisons between species and groups of PIT-tag fish are pending. A comparison of estuarine migration behavior between PIT-tagged fish we detected and

radio-tagged fish (steelhead and subyearling chinook salmon) that were and released by other researchers is also pending.

The subsequent detection at Jones Beach of PIT-tagged fish previously detected at Bonneville Dam enables calculation of a comparative survival estimate for inriver migrants to Bonneville Dam. In the Columbia River Basin in 2000, there were over 15 groups having greater than 10,000 PIT-tagged fish released. Estuarine detections from these major release-groups are generally sufficient to provide useful comparisons of inriver survival for the individual groups. Though preliminary at this date, the 95% confidence interval on the mean survival for inriver migrant chinook salmon and steelhead were 36 to 65% and 34 to 47%, respectively.

RECOVERY OF PASSIVE-INTEGRATED TRANSPONDER TAG CODES FROM PISCIVOROUS BIRD COLONIES IN THE COLUMBIA RIVER BASIN

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abstract

In 2000 we converted our PIT-tag recovery electronics to 134.2-kHz to comply with the basin wide conversion to International Organization for Standardization (ISO) PIT-tags. We used these equipment to again detect PIT tag codes from piscivorous bird colonies at various locations throughout the basin. The recovery efforts are ongoing, and data analysis on these data sets are incomplete at this time. Through 11 October 2000 we had recovered over 35,000 ISO-tag codes. We expect to complete the recovery efforts by 1 November 2000.

Since 1987, over 6 million juvenile salmonids have been tagged with passive integrated transponder (PIT) tags and released into the Columbia River Basin. In 1998 and 1999 we recovered over 130,000 400-kHz PIT-tag codes dating back to 1987 from tagged juvenile salmonids on piscivorous bird colonies located in the Columbia River Basin. Of the 130,000 tag codes recovered over 100,000 came from Caspian terns (*Sterna caspia*), 8,000 from double-crested cormorants (*Phalacrocorax auritas*), 5,000 from gulls (*Larus* spp.), and 5,000 from unknown predator species.

The majority of these tag codes (71,000) were recovered from the Caspian tern colony on Rice Island at river kilometer (Rkm) 34 in the Columbia River estuary. The impact from terns on Rice Island prompted managers to relocate the majority of terns nesting on Rice Island to East Sand Island (Rkm 8) approximately 26 km closer to the ocean. They hypothesized that moving the terns closer to the ocean would supply a greater abundance of non-salmonid prey and therefore reduce the impacts on salmonids. In 2000, they were successful in moving the majority (about 9,000 pairs) of terns to a colony on East Sand Island where we recovered over 24,000 ISO-tags from migration year 2000.

In addition to providing tag recovery data for the PIT Tag Information System (PTAGIS) data base we use these data to evaluate relative vulnerabilities of different salmonid groups to avian predation. We calculated vulnerabilities based on the proportion of PIT-tagged salmonids previously detected at Bonneville Dam and subsequently recovered on the Rice Island tern colony. For migration year 1999 we found a 5 to 1 preference for steelhead over yearling chinook salmon and a 3 to 1 preference for hatchery over wild chinook salmon. However, we found little or no preference for hatchery over wild steelhead and little or no preference for transported over non-transported steelhead or chinook salmon. In addition, we found no difference in the frequency of tags on the Rice Island tern colony for salmonids bypassed multiple times or salmonids that passed through the hydropower system undetected.

Characterization of Aspects of the Physical Environment Fish are Exposed to During Passage Through Kaplan Turbines Using an Autonomous Sensor

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Abstract

During December 1999 and January 2000, an autonomous sensor that measured pressure and tri-axial acceleration was sent through two Kaplan turbines at Bonneville Dam's first powerhouse. One of the turbines was equipped with a new minimum gap runner and the other was equipped with an original runner. Sensor fish were injected into the operating turbines at the units' wicket gates using a system designed to control the location of entry of the sensors into the turbine. Over the course of the study sensor fish were released at three locations (blade-hub, mid-blade, and blade-tip) and at 4 operating conditions in each turbine.

The passage route and exposure conditions were found to be very similar for replicate releases at specific locations and turbine operating conditions. Sensors released to pass near the blade-hub went deeper into the draft tube than sensors released at the other two locations and exited the draft tube deeper in the water column. Blade-hub released sensors passed through the tailrace under the tailrace backroll and remained deep in the water column until recovery balloons inflated and they were brought to the surface and recovered. Sensors released to pass near the blade-tip stayed high in the draft tube, were exposed to entrainment in the draft tube taillog slot, were frequently carried directly to the surface upon exit from the draft tube, were almost always entrained in or encountered the tailrace backroll, and in general were exposed to a higher level of turbulence than were blade-hub released sensors. Sensors released to pass mid-blade showed passage path and exposure characteristics intermediate between those of blade-hub and blade-tip released sensors but somewhat biases toward the turbine passage characteristics of blade-tip released sensors.

All of the sensors showed exposure to a "spike" in negative pressure as they passed through the turbine runner. Passage through the turbines from the time of exit from an injection pipe to exit from the draft tube was about 8 seconds, being somewhat longer for operating conditions with lower discharge. Exposure to turbulent conditions was longer, and in many cases had a higher magnitude, during passage through the tailrace than through the turbines' draft tubes. The sensor data clearly showed that hydraulic conditions, such as flow pulsing, initiated in the draft tube are propagated a significant distance downstream in the tailrace. There were no differences in passage conditions between the new MGR runner and the existing runner that could be detected in the acquired sensor data.

PASSAGE SURVIVAL AND CONDITION OF CHINOOK SALMON SMOLTS THROUGH AN EXISTING AND NEW MINIMUM GAP RUNNER TURBINES AT BONNEVILLE DAM FIRST POWERHOUSE, COLUMBIA RIVER

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Abstract

As part of the Corps' Turbine Survival Program and turbine rehabilitation, survival probabilities were estimated for hatchery-reared chinook salmon, *Oncorhynchus tshawytscha* (average total length about 166 mm) in passage through Units 5 (existing) and 6 (Minimum Gap Runner or MGR) at Bonneville Dam in November 1999 through January 2000. The new runner was designed to minimize the gap between the blade and hub, as well as between the blade tip and the discharge ring. This design improves the turbine efficiency and has the potential to improve fish survival. The primary objective of the study was to test the hypothesis whether the passage survival through the MGR unit equals or exceeds that of Unit 5. Secondary objectives were to (1) determine whether the turbine operating efficiency is correlated with passage survival; (2) determine the effectiveness of gap minimization; and (3) better identify injury mechanisms and in-turbine areas where fish injuries occur. Sufficient numbers of fish were to be released so that the resulting survival probabilities (24) would be within ≤±3%, 90% of the time. These objectives were accomplished by releasing fish through a specially designed induction system in order for fish to pass near the blade tip, mid-blade, and hub regions in each turbine at four discrete power levels. The four power levels at Unit 5 were: power level 1, near the lower end of the 1% operating limit; power level 2, slightly below the peak operating efficiency; power level 3, beyond the peak operating efficiency; and power level 4, near the upper 1% operating limit. The same power levels were tested for the MGR unit but with different operating efficiencies. These were: power level 1, below the lower 1% operating limit; power level 2, slightly below the peak operating efficiency but within the 1% operating limit; power level 3, beyond the peak operating efficiency but within the 1% operating efficiency; and power level 4, beyond the upper 1% operating limit.

Three separate metrics were used to assess the effectiveness of the MGR in fish passage: (1) estimation of absolute survival of turbine released fish relative to control fish released downstream into the turbine discharge, this included all fish, regardless of their condition, that were alive at 1 h and 48 h; (2) safe passage or unaffected fish (considered all injured fish and those showing loss of equilibrium as dead); and (3) relative survival, which was based on estimating survival of blade tip and hub released fish relative to those of the mid-blade region. All estimates apply only to the passage through the turbine runner and draft tube because the fish were released downstream of the stay vanes.

Recapture rates (physical retrieval of alive and dead fish) were high and met the pre-specified expectation used for sample size calculations. Recapture rates of treatment fish mostly exceeded 95% (range 94.6% to 99.1%) and those of controls were greater than 97% (range 97.6 to 100.0%). Most fish were recaptured within 500 yd downstream of the powerhouse; recapture times for controls averaged less than 7 min (range 5.1 to 6.6 min) while average times for treatment fish were higher (range 7.2 to 15.4 min).

Twenty of the 24 independent 48 h absolute survival estimates were ≥0.95 and two were 0.94. The two lowest estimates were 0.91 to 0.92; both were for Unit 5 blade tip fish released at power levels 2 and 4. High survival rates (≥0.97) occurred at both units for hub-released fish at all power levels.

Significant differences ($P<0.05$) in survival were observed between release locations but not between turbines ($P>0.05$). The 48 h survival of blade tip released fish was lower than for the mid-blade and hub released fish in both turbines. Survival between tip and hub released fish was significantly different ($P<0.05$); but not between tip and mid-blade released fish ($P>0.05$). Similar conclusions were observed from the statistical analysis of safe fish passage data. Safe passage estimates were less than 1.5% lower than the absolute survival estimates. The absolute survival and safe passage estimates can be categorized as having an increasing gradient from blade tip to mid-blade to hub. Absolute and safe passage survival probabilities are summarized below.

	Absolute Survival	Safe Passage Survival
	Unit 5 (Existing)	
Tip	Range = 0.908-0.957, Pooled = 0.931	Range = 0.900-0.947, Pooled = 0.919
Mid-blade	Range = 0.949-0.970, Pooled = 0.962	Range = 0.948-0.960, Pooled = 0.953
Hub	Range = 0.968-1.017, Pooled = 0.994	Range = 0.968-0.998, Pooled = 0.989
	Unit 6 (MGR)	
Tip	Range = 0.939-0.976, Pooled = 0.950	Range = 0.931-0.970, Pooled = 0.945
Mid-blade	Range = 0.954-0.971, Pooled = 0.961	Range = 0.947-0.965, Pooled = 0.953
Hub	Range = 0.974-0.982, Pooled = 0.980	Range = 0.956-0.986, Pooled = 0.969

With respect to the results of <u>relative</u> survival probabilities, hub released fish had higher survival probabilities <u>relative</u> to survival of mid-blade fish in both units (1.04 in Unit 5 and 1.02 in Unit 6) while the survival of blade tip passed fish was lower <u>relative</u> to that of mid-blade released fish (0.97 in Unit 5 and 0.99 in Unit 6).

No statistical correlation existed between passage survival and turbine operating efficiency in either turbine. Qualitatively, however, the highest point estimate of survival in both units, at all release locations, occurred at power level 3 (beyond the peak efficiency and towards the upper 1% operating limit); 48 h survival probabilities for this power level equaled or exceeded 0.96 (range 0.96 to 1.0).

The incidence of fish injury followed the opposing trends of survival estimates for the different passage routes and power levels of the two turbines. The MGR unit inflicted considerably less injury to passed fish; overall incidence of injury was reduced by approximately 40% (2.5% for Unit 5 and 1.4% for Unit 6). Most improvement in fish condition occurred at the blade tip; the injury rate for Unit 5 was 3.9% versus 1.9% for the MGR. Injury rates were also lower at the mid-blade region (2.3% for Unit 5, 1.0% for Unit 6). Few hub-released fish were injured in either turbine (0.7% for Unit 5 and 1.0% for Unit 6). The injury rates are summarized as follows:

	Number	Number Examined	Percent Injured

	Released		
	Unit 5 (Existing)		
Tip	966	928	3.9
Mid-blade	911	894	2.3
Hub	681	674	0.7
• **Total**	***2,558***	***2,496***	***2.5***
	Unit 6 (MGR)		
Tip	963	929	1.9
Mid-blade	903	81	1.0
Hub	681	668	1.0
• **Total**	***2,547***	***2,478***	***1.4***

At both turbines, most injuries were inflicted by shear and mechanical forces. Shear inflicted injuries were primarily characterized by partial decapitation, hemorrhaged or ruptured eye(s), and damaged gill(s) or operculum(s). Mechanical injuries were primarily lacerations, severed body, or external bruises.

Although experience from other sites demonstrates that hub gap minimization is beneficial to safe fish passage, its effectiveness at the Bonneville Dam MGR Unit 6 could not be fully verified because the terminus of the pipe for hub releases may have actually discharged fish some distance away from the hub and along the blade region. This was supported by the low injury rate, high survival rate, and absence of pinching type injuries typical of gap-related damage at Unit 5. Unfortunately, these findings came to light too late for corrective actions to be implemented in the field. Because the effect of closing the hub gaps in the MGR unit may not have been evaluated, additional fish releases known to pass the hub would be beneficial. However, a positive outcome of these findings is the challenge for turbine designers and engineers to fully characterize and understand the apparently benign condition experienced by “hub” released fish at both turbines over a wide range of operating conditions and to duplicate them throughout the turbine environment for safer fish passage.

The study succeeded in establishing that the fish passage success through the new MGR unit is less injurious and that survival is equal to or better than through an existing unit. This was most evident for blade tip released fish depending upon the power level; gap minimization between the blade tip and discharge ring in existing turbines may improve survival up to 3% for those fish transported through this area.

Finally, the evaluation uncovered a hither to unknown passage issue which, when resolved, may also further enhance the overall fish passage survival. About 2.3% of the released fish, primarily in the blade tip and mid-blade regions, were entrapped in the tailrace stop log slots. Turbulence can be high in this area and entrapment may cause delay for fish exiting the turbine draft tube, transport fish into a “back roll” or abrasive environment, subject fish to stress, and perhaps eventually increased predation. The magnitude of this potential problem and its possible solution could be ascertained by sampling naturally entrained fish in the tailrace stop log slots. It is unknown whether this situation is specific to Bonneville Dam, or occurs at other projects as well.

ADULT PACIFC LAMPREY PASSAGE AT LOWER COLUMBIA RIVER DAMS AND EVALUATION OF BONNEVILLE DAM MODIFICATIONS TO IMPROVE PASSAGE

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abstract

Radiotelemetry was used to assess passage of adult Pacific lamprey in the lower Columbia River for 4 years prior to this study. The first 2 years of study evaluated tagging procedures and documented the relatively poor passage efficiency of lamprey at Bonneville Dam. The next 2 years of radiotelemetry identified the spillway entrances, collection channels/transition areas, and counting stations as areas that obstructed or delayed lamprey passage. In 2000 the bulkhead at the southern spillway entrance (B-Branch on Bradford Island) was rounded to allow greater ease of lamprey attachment. In addition, velocity emanating from spillway entrances was lowered on alternate nights (1000 – 0400) to facilitate lamprey entrance. We used radiotelemetry to assess whether these changes improved lamprey passage success. In addition, receivers were added at the counting station areas to allow identification of specific obstructions to passage, and experiments were conducted at the Adult Fish Facility (AFF) counting window to assess the impacts of altering light quality.

We trapped lamprey in the Washington shore fishway at Bonneville Dam from May to September 2000. A total of 349 lamprey were surgically tagged with uniquely-coded radio transmitters: 299 were released below Bonneville Dam and 50 were released in The Dalles pool. Preliminary analysis indicated that lamprey released below Bonneville Dam approached the spillway entrance on Bradford Island (BBO monitor) 142 times and the spillway entrance at Cascades Island (CBO monitor) 49 times. A preliminary analysis indicated that during periods when velocity testing was not being conducted, 37% of the fish that approached the Bradford Island spillway entrance successfully entered and 43% of the fish that approached the Cascades Island spillway entrance successfully entered. We noted that there were greater accumulations of lamprey on the gates adjacent to the entrance at Cascades Island than at the Bradford B-Branch entrance. The velocity testing was started late in the season, and preliminary analysis indicated that 55 lamprey approached the spillway entrances during the night when the velocity regime was operating. At the Cascades Island entrance, 40 % of the lamprey that approached during the period of low velocity were successful, vs. 33 % during the control period at that entrance. At the Bradford Island entrance, 45 % of the approaches were successful during low velocity, while 48% were successful during high velocity.

We examined radio-tagged lamprey behavior in the counting window area at the Washington shore ladder (n = 34) and at the Bradford Island counting window (n = 39). Contrary to expectation, few lamprey were delayed at the lighted counting window area. However, based on preliminary analysis, it appears that the serpentine weirs both delay and obstruct lamprey passage. Red and white light treatments were alternated with dark

treatments at the AFF counting window from July 18 to Sept 19, 2000. Preliminary non-parametric analysis indicated that the numbers of lamprey caught in traps above the counting window treatment area did not differ significantly among light treatments. These results support the findings of both radiotelemetry and test flume experiments, and further indicate that lamprey migration is not obstructed by intense white lighting at the counting windows.

STUDIES OF PACIFIC LAMPREY PASSAGE IN THE TEST FISHWAY AT BONNEVILLE DAM, 2000.

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Abstract

A second year of studies were completed to evaluate swimming performance and behavior of adult Pacific lamprey in the test fishway at Bonneville Dam. We evaluated swimming performance of adult lamprey at night in a fishway ladder, effects of lips in orifices and diffusers on passage in ladders, and factors that affect behavior and passage at count windows. A total of 86 trials were run with 21 different test conditions using 450 lamprey.

At night, an average of 92% of the lamprey (9.2 of 10 fish used) successfully ascended the test ladder (three weirs separated by two 10-ft pools) in 1 hr, as compared to 58% passage during daytime and 60% passage at night with room lights on. When a 4 inch lip was added to the center weir orifice, passage rates were 70% at night and 28% during daytime tests. Adding a panel to imitate a diffuser just upstream from the center weir in the test ladder resulted in passage rates of 69% at night and 36% during daytime tests. We found that the lamprey could not attach to the diffuser grating to move through the submerged orifice, and so fish had to pass over the center weir to ascend the ladder. When a metal plate was placed on top of the diffuser grate just upstream from the orifice, to provide an attachment point for lamprey, passage at night improved to 95% but still averaged only 27% during daytime tests.

FOR TESTS WITH A SIMULATED COUNT WINDOW, THE FLUME WAS MODIFIED BY REMOVING THE WEIRS AND ADDING A CENTER DIVIDING WALL, PICKET LEAD, AND LIGHTS FOR NIGHTTIME VIEWING. THE PICKET-LEAD FENCES AT BONNEVILLE DAM WERE DESIGNED TO GUIDE SALMONIDS TO THE COUNT WINDOWS BUT THE BARS ARE SPACED WIDE ENOUGH APART THAT ADULT LAMPREY CAN PASS THROUGH INTO THE AUXILIARY WATER-SUPPLY CHANNELS. WE WANTED TO DETERMINE IF LAMPREY MOVING AT NIGHT WOULD AVOID THE BRIGHTLY-LIT 'COUNT WINDOW' SIDE OF THE CHANNEL AND PASS THROUGH THE PICKET LEAD INTO THE 'WATER-SUPPLY' (UN-LIT) CHANNEL. TESTS WERE RUN DURING DAYS AND NIGHTS WITH COUNT WINDOW VIEWING LIGHTS ON AND OFF. WE FOUND NO DIFFERENCE IN THE NUMBER OF LAMPREY THAT MOVED PAST THE COUNT WINDOW AT NIGHT WITH AND WITHOUT VIEWING LIGHTS ON. DURING THE DAYTIME TESTS, MORE FISH PASSED THE COUNT WINDOW WITH VIEWING LIGHTS ON THAN WHEN VIEWING LIGHTS WERE OFF.

Swimming performance and exhaustive stress in Pacific lampreys (*Lampetra tridentata*): implications for upstream migrations past dams

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abstract

Pacific lamprey populations in the Columbia River Basin are believed to be in decline. One factor, among several, potentially limiting lamprey production is the amount of energy they expend negotiating upstream passage facilities at dams. Because adult Pacific lampreys cease feeding in freshwater and have a finite amount of energy reserves with which to complete their life history, an excessive use of energy in negotiating fishways at dams could limit or stop the complex physiological processes necessary for sexual maturation and successful reproduction. Consequently, we initiated research in 1999 to provide information on the swimming performance and metabolic costs of exhaustive stress in these fish to help assess the efficacy of current upstream passage facilities at Bonneville dam. We estimated the critical swimming speed (U_{crit}) at 12ºC of radio-tagged and untagged fish to be 81 cm/s and 86 cm/s, respectively. Radio-tagged and untagged lampreys showed severe, but short lived, physiological responses to exhaustive exercise, including decreases in plasma pH and muscle glycogen levels and increases in hematocrit, plasma lactate, and muscle lactate concentrations. These physiological responses tended to be more severe in untagged animals. Mean active rates of oxygen consumption of fish at 10, 15, and 20ºC ranged from 200-300 mg/kg/h at 15 cm/s (spontaneous activity) to 1000-1200 mg/kg/h at speeds approaching U_{crit}. Finally, we have documented electromyogram activity from the swimming musculature of lampreys at rest, during active swimming, and at burst-type speeds using a new, smaller, surgically implanted radio transmitter. Electromyogram output was positively related to swim speed and was maximal during times of severe exertion. Collectively, our results provide a solid foundation towards estimating the metabolic costs of fish ascending the fishway at Bonneville Dam and should help identify areas of particularly difficult passage.

Evaluation of energy expenditure in adult salmon and steelhead migrating upstream in the Columbia and Snake rivers: understanding the influence of delay, fallback, water temperature, and dam operations on fish performance

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abstract

The Pacific Northwest is currently in the midst of an unprecedented decline of many stocks of anadromous salmonids. One factor potentially limiting salmonid production in the Columbia River basin is an excessive use of energy by adults migrating upstream, yet this notion has received little attention. Pacific salmon and steelhead (*Oncorhynchus* sp.) enter streams several months before they spawn and have a finite amount of energy reserves with which to migrate, produce gametes, and complete their life history. Today, the upstream migration of adults in the highly modified Columbia River Basin exposes fish to a variety of potential problems that could lead to excessive energy use. An energetically costly migration for adult salmonids could limit or stop the complex physiological processes necessary for sexual maturation and successful reproduction Consequently, we initiated research to document the energy expenditure of upstream migrating adult salmonids in the Columbia and Snake rivers to assess the potential influence of delay, fallback, water temperature, and dam operations (e.g., spill) on their bioenergetics and reproductive performance. During our first year, we focused on laboratory experiments addressing the relations between swim speed, oxygen consumption, and electromyogram (EMG) output of adult spring chinook salmon (SCHN). Specifically, our objectives were to: (1) measure active rates of oxygen consumption of SCHN at 8, 12.5, and 17ºC over a range of swimming speeds; (2) estimate the critical swimming speed (Ucrit) of SCHN at 12.5ºC; (3) monitor EMGs of red and white muscle in SCHN over a range of swimming speeds; and (4) assess some physiological changes in SCHN during and after prolonged swimming performance leading to fatigue. Oxygen consumption increased with increasing swim speed and temperature for all fish (N = 45). Mean active rates of oxygen consumption ranged from 100-150 mg/kg/h at 30 cm/s to 500-700 mg/kg/h at velocities near the critical swimming speed (U_{crit}). Depending on water temperature, oxygen consumption flattened out, or slightly declined, at or about 150 to 180 cm/s (~2 to 2.4 BL/s) and was variable between individuals. Estimates of critical swimming speed for these fish ranged from 125-178 cm/s (1.6-2.5 BL/s; N = 20). We collected EMGs from the red and white muscle of fish swimming at speeds from 30 cm/s to U_{crit}. In the red muscle, EMGs increased linearly with swim speed up to about U_{crit}; thereafter, EMGs in the red muscle generally

stabilized. In the white muscle, EMG output was relatively low at speeds up to U_{crit} and increased at higher speeds. Results on the physiology of fish during and after swimming to fatigue are pending. Our results indicate that the rate of oxygen consumption and EMG activity were strongly correlated with swim speed over a range of fish sizes and at three different temperatures. Together, our results provide a solid foundation towards estimating the energy use of fish migrating in the wild.

EVALUATION OF MIGRATIONAL DELAYS ON THE REPRODUCTIVE SUCCESS OF ADULT HATCHERY SPRING CHINOOK SALMON IN THE COLUMBIA AND SNAKE RIVERS

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abstract

During 2000, work was conducted to evaluate the use of the Torry Fish Fat Meter for estimation of the lipid content of whole salmon. This meter is based on a microwave sensor and has been widely used for food applications. This technique does not require the sacrifice of the animal as is necessary with conventional chemical analysis.

The overall objective of this research is to develop procedures to estimate lipid reserves of individual adult salmon as a function of their migrational travel history. Salmon tend to use lipid as an energy source in migration.

During the spring and summer, both pre-spawning and post-spawning adult spring chinook were obtained. These fish ranged from 1-7 kg. To assess the accuracy of the Torry reading, both Torry and conventional lipid measurements were conducted. The conventional measurements were obtained from subsamples of the ground-up whole fish.

Preliminary work was conducted to standardize our Torry measuring techniques. For adult salmon, the manufacturer recommends four reading on each side of the fish with the sensor oriented parallel and slightly above the lateral line. The Torry reading decrease from the head to tail due to decreasing lipid content. For example, for a post-spawning fish from Carson National Fish Hatchery (# 271), the readings were:

Reading 1 (Head End)	Reading 2	Reading 3	Reading 4 (Tail End)
1.9	1.3	0.8	0.7
1.8	1.4	0.8	0.7

The impact of tissue temperature on Torry readings was evaluated by measuring Torry reading of individual fish equilibrated at two temperatures . Temperature did not have a significant effect on the Torry reading at $p < 0.05$ (n=14). During one of the first tag interaction studies, we measured 30 consecutive Torry reading on the same fish. The Torry reading linearly increased during the series of measurements ($r^2 = 0.719$). Additional work showed that this increase was due to drying of the skin. Our standardized protocols for Torry measurements requires that the fish is held in water prior to the measurement and that excess water is removed from the fish by a single wipe of the hand immediately before the measurements.

The potential impacts of the Torry reading on both PIT and radio tags was evaluated. The following tests were performed on the PIT tags: (1) 10 reading with the PIT tag placed on the sensor head and parallel to the long axis of the sensor, (2) same as test 1 but perpendicular to the long axis of the sensor, (3) same as test 1 but with the PIT tag 1 inch above the sensor, (4) same as test 2 but with the PIT tag 1 inch above the sensor, and (5) 4 sets of 4 reading with the tag insert in an adult. The same tests were performed on the radio-tags, except that an additional series of 10 readings were made with the sensor head touching the antenna wire. At least 66 reading were made on each tag. All of the tags PIT and radio tags were operational at the end of the test; therefore it does not appear that the Torry meter has any effect on the operation of the two types of tags.

The impact of the PIT and radio tags on the Torry readings was evaluated by comparison of 4 sets of 4 Torry readings prior to and after the insertion of both tags. There was no significant effect of the tags on the Torry readings at $p < 0.05$ ($n = 10$).

Of the approximately 75 fish that will be used in the comparison of conventional and the Torry reading, only 35 have been analyzed for lipid content. Work is on-going and is expected to be completed by October 30. Based on the preliminary analysis, a significant relationship was found between the two measures of lipid content at a $p < 0.05$ ($n=35$).

The Torry meter uses a very low power level (_ 2 milliwatts), but its impact on egg development and reproductive success is not documented. Therefore, experimental work is underway with rainbow broodstock to test any potential effects. Three treatments have been selected: Control - no Torry measurements, one test - a single series of 8 Torry readings, and multi-tests - Torry measurements repeated ever 3 weeks until spawning. The initial Torry reading were started 6 months prior to the expected date on spawning. At this time (May 8, 2001), the broodstock have been tested twice. The number of eggs produced, egg size, and green-egg to eyed egg survival will be will be compared.

EVALUATION OF FISH PASSAGE BEHAVIOR THROUGH SUBMERGED ORIFICES AND OVERFLOW WEIRS IN RELATION TO ORIFICE PIT-TAG DETECTOR INSERTS

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abstract

In 2000, we used underwater video technology to study the passage of adult salmonids at two weirs at Cascades Island ladder, four weirs at Washington shore ladder, and four weirs at the adult fish trap exit ladder at Bonneville Dam. Our first objective was to determine baseline data on proportions of adult salmonids passing overflow weirs and submerged orifices at Washington shore weirs where PIT-tag detector inserts would be installed in 2001. Our second objective was to confirm the results seen in 1999 at Cascades Island ladder that a weir with an orifice PIT-tag detector insert has no adverse effect on adult salmonid passage. Our third objective was to determine the efficacy of adult PIT-tag detectors in enumerating tagged adult salmonids as they passed through the orifice detector inserts at the adult fish trap. The fourth objective was to conduct a literature search for any historic, baseline data concerning passage routes of fish regarding proportions of fish using submerged orifices vs. overflow sections.

At Washington shore ladder weirs 51, 52, 53, and 56 were monitored with video cameras (8 underwater, 8 overhead) in the spring, summer, and fall periods for a total of 94.5 hours which totals 1512 hours of video tape to review. As of September 20, 2000 650 hours of tape had been viewed and analyzed. Proportions of spring fish using the overflow sections (net passage) are 2.8% for all four weirs, 2.2% for weir 51, 2.5% for weir 52, 4.8% for weir 53, and 1.2% for weir 56. Proportions of upstream only passage using the overflow sections ranges from 1.4% to 5.2% and is 3.2% for all four weirs. Proportions of downstream only passage using the overflow sections ranges from 8.9% to 26.7% and is 19.3% for all four weirs. Obviously a higher proportion of fish use the overflow sections when falling back than when passing upstream. Fish numbers observed so far have been classified as chinook 1218, sockeye 69, steelhead 4,573 (492 hatchery, 837 wild, 3244 not specified), unknown salmonid 179, shad 2, lamprey 3, and unidentified 1522 for a total of 7568 passage observations. Not enough data is available as yet for meaningful results in the summer or fall periods.

At Cascades Island, weirs 52 and 53 were monitored with video cameras (4 underwater and 6 overhead) in the spring, summer, and fall periods for a total of 66 hours which totals 660 hours of video tape to review. Weir 53 had a non-operational PIT-tag detector insert in the south side submerged orifice as in 1999. As of September 20, 2000 only 48 hours of video tape had been reviewed and the data is insufficient to present. In 1999 we monitored for 225.5 hours in the spring, summer, and fall and showed that fish did not in any way avoid the orifice with the PIT-tag insert housing and in fact used it significantly more than the unmodified orifice. Fall overflow usage figures were 6-7% for upstream passage and 1-2% for downstream passage.

At the adult fish lab, 119 salmonids were tagged with visual streamer tags and PIT-tags in the spring and released to exit the fish lab and return to the Washington shore ladder. Weirs 44, 45, 47, and 48 at the adult fish lab exit ladder section were outfitted with 18" orifice PIT-tag inserts for the first test week and 26" orifice PIT-tag inserts for the second test week. PIT-tag detector systems for two different manufacturers were used but these data were not broken out for our report. For the 18" orifices 168 of 173 (97.1%) of the PIT-tag fish passage events through all four weirs were detected by the PIT-tag detectors, and for the 26" orifices 117 of 124 (94.4%) were detected. In the fall, 159 salmonids were tagged but only weirs 45 and 48 were outfitted with PIT-tag inserts, 18" inserts for the first test week, 26" inserts for the second test week. These inserts had special shielded housings to reduce "noise" interference. For the 18" orifices, 105 of 105 (100.0%) of the PIT-tag fish passage events through both weirs were detected by the PIT-tag detectors, and for the 26" orifices 170 of 172 (98.8%) were detected. For the entire year at all weirs and both 18" and 26" orifices, 562 of 576 (97.6%) PIT-tag fish passage events were detected. Of those, 499 of 510 (97.8%) were upstream passages and 63 of 66 (95.5%) were downstream passages. Overall, the 18" orifices were 97.8% effective and the 26" orifices were 97.3% effective in detecting PIT-tag fish passing.

The literature search has resulted in very few applicable reports concerning the ratios of fish using the overflow weirs to submerged orifices. Over 250 articles and reports that were supplied as the result of our keyword search resulted in about 50 potentially useful reports. So far, only two reports have been found that do cite the proportions of fish using the overflow sections of weirs in ladders. They were conducted at John Day and Bonneville dams in the 1960's and reported proportions of steelhead using the overflow section as 2% and 34.1% and sockeye proportions of 55% and 88.7% respectively. However, one study used weir configurations that are not similar to any current overflow weir designs for Columbia and Snake River fishways and the other was conducted in a laboratory setting. We feel that the data collected in 1999, 2000, and beyond by this study will be much more pertinent and meaningful for developing baseline data on proportions of fish using overflow sections of weirs on the Columbia and Snake River fishways than any data from other fishways around the country or in other countries.

Identification and Enumeration of Steelhead (*Oncorhynchus mykiss*) Kelts in the Juvenile Collection Systems at Lower Granite and Little Goose dams, 2000.

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abstract

Unlike most Pacific salmon, steelhead (*Oncorhynchus mykiss)* may spawn more than once during their lifetime. Because steelhead kelts (post-spawned individuals) could be a resource for rebuilding depleted wild populations by contributing repeat spawners, research has been initiated to enumerate kelt passage and to reduce dam passage mortality of kelts. Adult steelhead entering the juvenile collection systems of Lower Granite Dam (LGR) and Little Goose Dam (LGO) were examined with ultrasound to assess maturation status, to estimate kelt abundance, and to test and develop morphological traits to visually distinguish kelts from pre-spawners. Our 2000 study objectives are a continuation and expansion of kelt research initiated at Little Goose Dam in 1999. All data should be considered preliminary until the annual report for this research project is prepared for Corps review (anticipated December of 2000).

We used ultrasound images of visceral anatomy to identify kelts and pre-spawners among a 32.4% and 8.1% sample of adult steelhead removed from Lower Granite and Little Goose bypass facilities, respectively. Research was conducted during the peak fallback season of April through June, 2000. Kelts identified by ultrasound at Lower Granite bypass were marked with Floy tags and released into the tailrace to resume their migration. Floy tags that were subsequently observed at downstream locations (e.g., Little Goose bypass) were then used to estimate the total in-river kelt population from mark re-capture equations. The development of visual identification methods for maturation appraisal was another primary objective of the study. Corps personnel were trained by our staff – prior to the onset of the 2000 fish passage season – to visually identify the spawning status (i.e., kelt or pre-spawn) of adult steelhead removed from juvenile bypass facilities based on the fish's abdominal appearance (visual kelt ID methods utilized in 2000 training were developed from 1999 data).

Kelt Abundance: Based on ultrasound examinations we calculated that 95.9% (0.948 $_{\text{lower 95\% C.I.}}$ to 0.970 $_{\text{upper 95\% C.I.}}$) and 93.1% (0.869 $_{\text{lower 95\% C.I.}}$ to 0.969 $_{\text{upper 95\% C.I.}}$) of all the adult steelhead removed from LGR and LGO, respectively, during the study period were steelhead kelts. In total, we estimated that 3,956 of 4,182 adult steelhead removed from the LGR bypass were kelts and that 1,432 of 1,532 adult steelhead removed from the LGO bypass were kelts. We floy tagged and released 1,135 kelts (~29% of all the kelts arriving at LGR during the study) into the tailrace of LGR between 4 April and 7 June, 2000. Of these, 104 (9.2%) were recorded reaching the Little Goose bypass, 41 (3.6%) to the Lower Monumental bypass, and 7 (0.6%) to the McNary bypass facility. Based on the total number of floy tags recovered at Little Goose Dam (*n*=104), an estimated 16,745 steelhead kelts (13,821$_{\text{lower 95\% C.I.}}$ to 20,290 $_{\text{upper 95\% C.I}}$) were present in the Lower Snake R. at Lower Granite Dam during the study period. An estimated 8,127 wild ESA-listed kelts (6,219$_{\text{lower 95\% C.I.}}$ to 10,259$_{\text{upper 95\% C.I}}$) attempted to emigrate in the Lower

Snake R. during the spring of 2000. These fish represent between 51% and 85% of the entire wild steelhead run counted passing the LGR fishway from 1 June 1999 to 30 May 2000.

Accuracy of Visual Identification Methods: Ultrasound examinations at the dams revealed that visual methods misclassified 62% (81%♂ and 48%♀) of all pre-spawners as kelts but only misclassified 3% (5%♂ and 2%♀) of kelts as pre-spawners. However, given that the majority of fish examined were kelts, overall misclassification was only 7% during the study period.

Morphological Maturation Appraisal: Consistent with data generated during our 1999 study, statistical analysis (logistic and tree-classification models) suggests that the appearance of the steelhead abdomen (e.g., thin/imploded or fat) is the primary visual indicator of maturation status. Female steelhead were 25 times more likely to be kelts if they had an imploded abdomen, while male steelhead with imploded abdomens were only 3 times more likely to be kelts. Models also suggest that fin-wear (ranked by degree of severity), coloration (dark, intermediate or bright) and the time of examination (e.g., April versus May) can also be used to distinguish pre-spawners from kelts at the dams. We recommend the continued use of visual methods to enumerate kelt passage at Snake R. collector dams, however, caution that pre-spawner abundance may be underestimated – especially in males. Despite the overall high accuracy of visually methods (93% correct identification in 2000), ultrasound appears to be the only consistent, rapid and accurate method to assess maturation status among pre-spawn steelhead. The need for future ultrasound kelt identification at Snake R. bypass facilities should depend, in part, upon study objectives (e.g., kelt enumeration or kelt collection for reconditioning).

The good condition, ready accessibility, and abundance of wild Snake R. kelts would make them excellent candidates for reconditioning studies, which theYakama Nation and CRITFC are currently conducting on the Yakima River. Based on the results of this Corps funded kelt identification and enumeration research project, we encourage the Walla Walla District and regional managers to consider the possible merits of aiding wild Snake River kelts to spawn again via reconditioning and/or kelt transportation.

Evaluation of Steelhead Kelt Passage Routes at Bonneville Dam, 2000

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Abstract

We (FFU) used radio telemetry to monitor the downstream passage behavior of radio-tagged steelhead (*Oncorhynchus mykiss)* kelts (i.e., potential repeat spawners) released above Bonneville Dam (BON). The objectives of this research were to determine: 1) the behavior of kelts once in the near dam forebay areas; 2) the behavior of kelts once in proximity to bypass structures and potential passage routes (i.e., Prototype Surface Collector (PSC), Submersible Traveling Screens (STS), Extended Submersible Bar Screen (ESBS), spillway, ice/trash sluiceways, and turbine units; 3) the residence times of kelts in forebay areas; and 4) the time and route of passage.

We attached radio-tags to 147 Snake River (SnR) steelhead kelts transported them to either the Cascade Locks or Stevenson boat ramps and released them. In addition, we radio-tagged 12 air-spawned Hood River (HR) female steelhead and transported and released them at the above stated locations to evaluate the downstream passage behavior of these Bonneville Pool steelhead. We contacted 98% of the tagged and released steelhead above BON and 89% of the steelhead after passing BON. We have no contact records for 3 of the released kelts (2 SnR, 1HR). Two air-spawned steelhead from the HR, were released at CCL and subsequently were only contacted at sites above BON. Our last contact record for 13 of our kelts was in forebay areas. Similarly, our first contact with 13 of our kelts was at the exit station 2 mi. below BON.

Roughly 41% (52 of 128) of our full path kelts passed through Powerhouse I (PH I), 46% (59 of 128) through the Spillway, and 13% (17 of 128) through Powerhouse II (PH II). Full path kelts (N=128) are those fish which we contacted in the forebay, and in the tailrace and/or at the exit stations 2 mi. or greater below BON. At PH I 87% (45 of 52) of our tagged kelts passed through the turbine units, with 4% (2 of 52) kelts being passed by the PSC into the sluiceway, and 10% (5 of 52) kelts being guided by STS into the DSM channel. At Ph II 65% (11 of 17) of our tagged kelts passed through the turbine units, with 6 kelts passing through the PH II Juvenile Bypass Flume. Overall, 45% of our full path kelts passed through turbine units, 45 % passed through the spillway, and 10% were passed through bypass systems.

BACKGROUND INFORMATION FOR 2000 ADULT PASSAGE PROGRAM:

FISH TAGGED, TIMING OF RUNS, FLOWS, SPILLS, AND TEMPERATURES

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abstract

Background information for 2000 program: fish tagged, timing of runs, flows, spills, and temperatures

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We have used radiotelemetry since 1996 to assess passage of adult salmon and steelhead at lower Columbia River and Snake River dams, through reservoirs, and into tributaries. These data have been used to evaluate fish responses to flow, spill, and other river conditions, and to evaluate measures to improve passage.

In 2000, we gastrically-implanted radio transmitters into spring/summer chinook salmon, fall chinook salmon, and steelhead. Of the 1132 spring/summer chinook salmon tagged, 973 were released downstream from Bonneville Dam and 159 were released in the Bonneville Dam forebay. Of the 1117 fall chinook salmon tagged, 744 were released downstream from Bonneville Dam and 373 were released in the Bonneville Dam forebay. Of the 1160 steelhead tagged, 844 were released downstream from Bonneville Dam, and 316 were released in the Bonneville Dam forebay. Spring chinook salmon were tagged from 4 April to 31 May, and summer chinook salmon were tagged from 1 June to 31 July. Fall chinook salmon tagging began on 1 August, steelhead tagging began on 1 June, and all tagging efforts ceased on October 23. We began the season by tagging 10 fish each day, increased the number of fish tagged as abundance increased, then reduced the number to 10 fish per day as the run decreased. The number of fish tagged each day closely matched the proportion of the run for each species.

The year 2000 was a relatively low river flow year compared to the previous 5 years. During this project, 1996 and 1997 were relatively high flow years and 1998 and

1999 were intermediate. The river flow peaked early in 2000 (late April) compared to higher flow years when flow generally peaked in mid-June. Spill volume showed a pattern similar to river flow, with the least spill volume in 2000 (the year of lowest flow), and the greatest spill volume in 1996 and 1997 (the years of highest flow). The warmest lower Columbia River temperatures observed in the previous 5 years were in 1998, while 2000 had comparatively cool river temperatures. The lower Snake River also had warmest river temperatures in 1998, however river temperatures in 2000 were intermediate.

Spill tests were conducted at several lower Columbia and Snake River dams in 2000. The daytime spill at Bonneville Dam was experimentally manipulated to determine how fallback rates are effected by increased spill. The control condition limited daytime spill to 75 kcfs, with nighttime spill ranging from approximately 145 to 85 kcfs (this varied depending on power demand and total river flow). During the test condition, daytime spill was not controlled, resulting in high daytime and high nighttime spill. The spill volume at The Dalles Dam was 40% of river flow during all times of the day and night. The daytime spill volume at John Day Dam alternated between 0 and 30% of river flow and nighttime volume was 60%. Ice Harbor Dam daytime spill volume varied from 45 kcfs during the day (to enhance adult passage) to 100 kcfs during the night (to control gas levels).

Effects of Orifice Gate Closures on Radio-tagged Spring and Summer Chinook Salmon Behavior at Bonneville, The Dalles, Lower Monumental and Little Goose Dams

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We evaluated median times between first approach and first entrance into fishways for radio-tagged fish to determine if closing the orifice gates had a negative effect on passage of fish at the dams. Orifice gates were anternately open and closed in a block design test at Bonneville powerhouse I and were open at powerhouse II during the period of salmon migration. We examined distributions of first approach and first entrance locations for radio-tagged fish at Bonneville from 1996 –1998 and compared them to 2000 data. We calculated passage times and the mean number of entries and exits per fish with orifice gates open or closed.

All orifice gates at The Dalles, Lower Monumental, and Little Goose dams were closed in 2000 which was a change from 1996-1998 when they were open. For these dams, we made inferences about the effects of orifice gate closures in 2000 based on comparisons of median times to enter after making first approach, distributions of first approach and first entrance locations, passage times and mean entries and exits per fish for all four years.

Effects of Spill on Fallback and Passage of Adult Chinook Salmon at Bonneville Dam, 2000

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Tests were conducted to evaluate effects of two levels of daytime spill for juvenile salmonid passage on passage and fallback of adult chinook salmon and steelhead at Bonneville Dam. At Bonneville Dam, spill was alternated between high and low spill volumes through the spring and summer migration to produce replicate blocks of spill treatment. We compared the proportions of fish that fell back at Bonneville Dam for each block and spill level.

During 2000, daytime spill ranged from about 50 to 144 kcfs. Within this range of spill we found little correlation between spill level and fallback rates. Fallback rates averaged 15% when spill was less than 80 kcfs, and 19% when spill was 80 kcfs and higher, and the difference was not statistically significant (P = 0.3497, n = 29 blocks). When fish that had moved upstream at least as far as Cascades, OR, before falling back at Bonneville Dam were excluded, fallback rates averaged 11% and 15% for the low and high spill levels (P = 0.3263, n = 29). Results contrast with those from previous years when spill volumes at Bonneville Dam were significantly higher and associated with higher fallback rates. There was a significant date effect with fallback--fallback rates were lower in summer (averaged 6%) than in spring (14%) for fish that did not migrate upstream from the dam before falling back (P = 0.0023).

Migration Routes of Salmon and Steelhead Released on the Oregon Shore In the Forebay of Bonneville Dam, 2000

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In 2000, a test was conducted to determine if fewer adult salmon and steelhead would enter the spillway and fall back over the dam if they were released on the Oregon shore, or the south side and north side of the navigation lock guide wall in the forebay of Bonneville Dam. The high fallback rates at Bonneville Dam are caused by the location of the Bradford Island exit, the fish's tendency to migrate along the shorelines, and spill at the dam. Starting in May, spring and summer chinook salmon, outfitted with radio transmitters in the Adult Fish Facility, were transported across the dam and released through a tube into a recovery pen on the Oregon shore at the upstream end of the navigation lock wall. The fish could leave the pen whenever they wished. We added steelhead to the fish released on the Oregon shore in June, and fall chinook in early August. In late August we started releasing fish also on the south side and north side of the navigation lock guidewall just upstream from the lock. For the entire migration season, we released 159 spring/summer chinook and 373 fall chinook salmon, and 316 steelhead at the three sites near the Oregon shore. For this presentation, we determined the migration routes of 180 fish released on the Oregon shore, 93 released on the south side of the guidewall, and 85 fish released on the north side of the guidewall.

Seventy-four percent of the fish released on the Oregon shore migrated upstream out of the forebay along the Oregon shore, 8% fell back through the spillway, and 2% fell back through the navigation lock. Similar percentages of fish released on the south and north sides of the guidewall (73% and 69%) migrated up the Oregon shore, but none fell back through the spillway (there was no spill after 31 August), and 5% and 1% fell back through the navigation lock. All three of the species of fish followed similar migration routes out of the forebay. From the preliminary analysis, we believe releasing fish on the Oregon shore should significantly reduce the fallback rate at Bonneville Dam.

Depth and Temperature Profiles of Salmon and Steelhead While They Migrated from Bonneville to Lower Granite Dams with RDST tags.

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During April through October 2000, we outfitted 228 spring/summer chinook salmon *Oncorhynchus tshawytscha*, 78 fall Chinook salmon, and 175 steelhead with radio-data storage tags (RDST) that consisted of a component that recorded pressure and temperature, and a radio transmitter that was used to determine the location of tagged fish. Fish were trapped and tagged at the adult fish collection facility at Bonneville Dam. We inserted a 90 mm x 20 mm, 34 g, RDST tag into the stomachs of fish and released them 10 km downriver from the dam. Pressure was recorded at 5 sec intervals and temperature was recorded at 1 min intervals as the fish migrated from Bonneville to Lower Granite Dam, where the fish were recaptured and the tag removed. We monitored fish movements with fixed site receivers at dams and along their migration route in the lower Columbia River reservoirs, in the lower Snake River reservoirs, and at the Hanford reach and Priest Rapids Dam in the mid Columbia River. Location data from fixed-site receivers were supplemented with mobile tracking by boat and truck.. Depth (m) and temperature (C) profiles over time for adult salmon and steelhead were prepared by integrating daily, hourly, and minute means for depth and temperature with radio telemetry records So far, 213 of the 481 (44%) tagged fish have been recaptured: 52% at Lower Granite Trap, 34% in fisheries, 10% at hatcheries, 2% at weirs, and 2% at other locations. We provide examples of the depth and temperature profiles of fish as they migrated from release sites to recapture sites.

Migratory Patterns of Adult Chinook Salmon and Steelhead in the Lower Snake River and Columbia River in Relation to Dissolved Gas

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Dissolved gas supersaturation in the Columbia and Snake rivers routinely occurs during the spring and summer freshet when water spilling over hydroelectric dams entrains large volumes of air creating a high dissolved gas plume below the dam spillway. During the spring and summer of 2000, adult spring and summer chinook salmon and steelhead were tagged with radio transmitters. RDST tags (data storage units with pressure and temperature sensors plus a radio transmitter) were used in addition to regular transmitters to determine in situ swimming depths in relation to water with higher dissolved gas concentrations. Swimming depth is critical to fish survival in supersaturated water. Due to hydrostatic pressure, each meter of depth is equivalent to a 10 % reduction in gas saturation.

Transmitter equipped fish released downstream of Bonneville Dam were monitored as they migrated upstream past the Columbia River dams and Lower Snake River dams. Detailed tracking of fish by boat was concentrated at Bonneville and Ice Harbor dam tailraces with respect to the dissolved gas plume, and at the Snake River confluence with respect to the higher dissolved gas Snake River water flowing into the Columbia River.

Project study objectives include collaborating two-dimensional fish migration tracks to outputs from a dissolved gas model to identify if there is an avoidance response to higher dissolved gas areas. Evaluating depths of migration through dissolved gas plumes and dam fishways to determine the extent of exposure to various dissolved gas conditions, and comparing survival based on the extent of exposure.

Preliminary analysis of data suggests that during high flow in the Snake River downstream of Ice Harbor Dam fish did not show a shoreline preference. As water levels dropped in the Snake River below Ice Harbor Dam fish migration was confined to the river channel running parallel to the north shore. Changes in migration patterns were also observed at the Snake River confluence with regards to the Snake River flowing into the Columbia River. As the temperature differential increased between Snake and Columbia River water, fish hesitated to enter the warmer more turbid Snake River flow and regularly migrated along the visibly distinct line. Fish migrating upstream to Bonneville Dam from the release site did not show a particular shoreline preference. The majority of the fish tracked utilized both shorelines during migration crossing between shorelines in similar locations.

Migration Behavior of Steelhead During Summer and Fall in Relation to Spill and Temperature

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During the summer and fall of 2000, over 1200 adult steelhead were outfitted with either radio or RDST tags (radio and data storage tags) at the adult fish facility at Bonneville Dam. The RDST tags monitored water temperature every minute and pressure every five seconds for a period of 40 d. Tagged steelhead were released from five locations downstream from and at Bonneville Dam, and their movements were monitored with fixed receivers and by mobile tracking by boat and truck. Migration routes and behavior of tagged steelhead below Bonneville and Ice Harbor Dams were assessed for times when spilling did and did not occur at each dam. Migration behavior was also monitored at the confluence of the Snake and Columbia Rivers, in the Bonneville and John Day pools in and around the mouths of tributaries where tagged fish were located. The temperature of selected tributaries were monitored with temperature data loggers and the daily records of Cascade Hatchery. Temperature profiles were obtained at the mouths of the tributaries with a Unidata temperature data logger which could record temperatures at depths up to 9.1 m. Periods and duration of use of tributaries by tagged steelhead was assessed and compared to data from RDST tags.

Migration Behavior of Fall Chinook in Relation to Spill and Temperature in 2000

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During the 2000 fall chinook salmon run in the Columbia River, our research focused on establishing migration patterns in response to spill, river temperatures, and inflow from cold water tributaries. Below Bonneville and Ice Harbor dams chinook salmon were tracked by boat to observe the routes taken by salmon in relation to the plume of water from the spillways. Our objective was to determine if movements differed between times of spill and non-spill, perhaps indicating reaction to dissolved gas concentrations. Upstream from Bonneville dam, salmon were tracked as they approached the confluence of cold water tributaries. Our objective for this tracking was to document any response when cooler water was encountered and whether the salmon entered and used tributary streams as thermal refuges on their way up stream. Duration of time spent in tributaries was determined from records of fish location obtained by tracking from boat and truck, and receiver sites.

Migration routes of fall chinook salmon did not differ between times of spill and no-spill. Twelve complete tracks of salmon were made from either the Skamania or Dodson release site until entry into Bonneville Dam's lower boat restricted zone. Ten of the twelve fish moved from one side to the other at least once and several individuals made multiple crossings. Two salmon did not change sides of the river, choosing to move up and enter the boat restricted zone on the same shore from which released. Fall Chinook did not appear to prefer either shore upon final approach to the dam. The tracks resulted in five fish entering the boat restricted zone along the north shore, four on the south shore and three in midstream. Furthermore, patterns of fish behavior did not change after September first when spill ceased. Finally, all fall Chinook approaching Ice harbor dam were recorded migrating up the main channel along the north shore before moving directly into the tailrace a few hundred meters downstream from the dam.

Most fall chinook salmon tracked upstream from Bonneville Dam past a tributary did not respond to the cooler water when approaching the stream and moved quickly past. Two supportive examples were fish 13-38 and 24-22 tracked on the 18th and 22nd of August, respectively. They were tracked from below Bridge of the Gods upstream past Herman Creek without the slightest hesitation or alteration in course at a time when 35 tagged steelhead were holding in the mouth of this small stream. For the most part, relatively few chinook salmon appeared to delay their migration and congregate at the mouths of tributaries. The few tagged chinook salmon observed in the tributaries may have been destined to spawn there or return to a hatchery on the tributary.

Fallback, Escapement and Reach Survival of Radio-Tagged Adult Salmon and Steelhead through the Columbia River Hydrosystem

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In the years 1996 to 1998 we outfitted 3,911 spring, summer and fall chinook salmon *Onchorhynchus tshwaytscha*, 577 sockeye salmon *O. nerka*, and 1,740 steelhead *O. mykiss* with radio transmitters at the Bonneville Adult Fish Facility and released them downstream from Bonneville Dam. We used fixed and mobile radio receivers to record fish behavior at dams and in fishways, fallback and reascension past dams, and entry into major Columbia and Snake river tributaries. We used telemetry data to calculate passage success at dams and upstream migration rates. We determined final distribution and fate of all fish with telemetry data supplemented with recapture information from hatcheries, fisheries, and from transmitters located in spawning areas and along rivers.

For this presentation, we assessed several aspects of adult survival and escapement. We compared escapement rates to monitored tributaries or the uppermost monitoring sites for fish that did or did not fall back at mainstem dams and compared fallback rates for specific stocks. We calculated reach survival estimates through each hydrosystem segment to partition fish not accounted for by recapture or entry into tributaries. We also compared fallback history, injury at time of tagging, release date, size, sex, and fin clips for fish that were unaccounted for to fish that escaped to tributaries or were recaptured.

Escapement to monitored tributaries or mainstem spawning areas or hatcheries was 76-81% for spring and summer chinook salmon, 76% for sockeye salmon, 69% for fall chinook salmon, and 59-62% for steelhead. An additional 5-8% of spring and summer chinook and sockeye salmon, 13% of fall chinook salmon, and 11% and 20% of steelhead were recaptured in mainstem fisheries. Thirteen to 16% of spring and summer chinook salmon, 10% of sockeye salmon, 19% of fall chinook salmon, and 20% and27% of steelhead could not be accounted for.

Fish that fell back at one or more dams escaped to tributaries at significantly ($P < 0.05$) lower rates than fish that did not fall back. Significantly lower escapement was associated with fallback at every lower Columbia River and Snake River dam for spring and summer chinook salmon and steelhead in most, but not all years. Differences in escapement were not significantly different for fall chinook and sockeye salmon that fell back at Bonneville or McNary dams. Fish that fell back multiple times tended to escape to tributaries at lower rates than fish that fell back one time, especially for upriver stocks.

On average, 20-30% of spring and summer chinook salmon that escaped to lower Columbia River tributaries were recorded falling back at least once. Thirty to 40% of spring and summer chinook salmon that returned to Snake River tributaries fell back, compared to about 15-25% of mid-Columbia River stocks. Proportions of steelhead that fell back averaged about 20% for stocks that passed Lower Granite Dam, and were highest (20-40%) for fish that returned to the John Day, Umatilla, Walla Walla, Yakima, and Tucannon rivers.

For all species except sockeye salmon, reach survival rates were lowest through the Bonneville Dam pool to the top of The Dalles Dam. Survival rates for all species were between 0.92 and 0.99 for each reach we studied. Losses (fish unaccounted for) through the Bonneville-The Dalles reach averaged 6.5% for spring and summer chinook salmon and 7.6% for steelhead; losses were 3% for sockeye salmon and 7.5% for fall chinook salmon. Average losses through The Dalles, John Day, and McNary reaches were 4.0-5.1% for spring and summer chinook salmon, 5.0-5.3% for steelhead, 2.1-3.9% for sockeye salmon, and 1.2-7.2% for fall chinook salmon. In the Snake River, losses from the top of Ice Harbor Dam to the top of Lower Granite Dam averaged 2.7% for spring and summer chinook salmon and 7.9% for steelhead.

We tested for differences in physical characteristics or behavior among accounted-for and unaccounted-for spring and summer chinook salmon. Salmon that fell back at one or more dams were unaccounted for at significantly ($P < 0.05$) higher rates than fish that did not fall back in 1997 and 1998. At individual projects, unaccounted-for rates were significantly higher for chinook salmon that fell back at Bonneville and The Dalles dams in 1997 and 1998 ($P < 0.005$), at John Day Dam in 1996 and 1998 ($P < 0.05$), and at McNary Dam in all years ($P < 0.005$).

We found no significant differences ($P < 0.05$) in the proportion of unaccounted-for male or female fish, spring- or summer-run fish, fish with or without fresh marine mammal scrapes or bites, or fish with or without descaling at the time of tagging. A significantly ($P < 0.01$) higher proportion of fish with fin clips were unaccounted for in 1996 than fish without clips, but not in 1997 or 1998. A significantly ($P < 0.01$) higher proportion of fish with head injuries at time of tagging were unaccounted for in 1997 and 1998 than fish without head injuries. In 1996 and 1997, fish in smaller fork-length categories tended to be unaccounted for at higher rates than larger fish. The proportion of unaccounted-for fish in each time-segment of the runs decreased from early to late tagging date in 1996 ($r^2 = 0.64$), but not in 1997 or 1998.

Distribution of Adult Spring and Summer Chinook Salmon in Columbia and Snake River Tributaries as Assessed with Radio Telemetry in 2000

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In 2000, we trapped 1,133 adult spring and summer chinook salmon at Bonneville Dam and outfitted them with radio transmitters. The fish were released downstream of the dam and monitored as they migrated upstream past dams, through reservoirs and into tributaries in the Columbia and Snake rivers. We compared the proportion of fish passing Priest Rapids and Ice Harbor dams, and determined the distribution of final observations of the radio tagged fish, noting those harvested and those entering tributaries and hatcheries.

Discrepancies in Counts of Spring Chinook Salmon and Steelhead at John Day, McNary, Ice Harbor, and Priest Rapids dams in 2000 Versus Passage of Fish with Transmitters

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Counts of adult salmon and steelhead at adjacent dams often vary widely for a variety of reasons. When the count at the upstream dam is less than the count at the downstream dam, the discrepancy can be caused by events between the dams such as: fish entering tributaries, fish harvested, and fish dieing. If the count at the upper dam is larger than the count at the downstream dam, then count error is likely involved unless a large number of fish pass a dam via the navigation lock, which does not usually happen, or there is a high fallback rate that inflates counts at one of the dams.

In 2000, the count of spring and summer chinook salmon at McNary Dam (85,700) was less than the number of salmon counted upstream at Ice Harbor, Priest Rapids, in the Yakima River and at Ringold Hatchery by more than 17,300 fish (20% of the count at McNary). Based on our initial analysis of salmon with transmitters recorded at those same sites, 616 salmon passed over McNary Dam (corrected for fallbacks), and all but 55 (9% of the McNary count) were accounted for at the upstream sites. The discrepancies were +9% for fish with transmitters versus -20% for counts. A portion of the fence that guides fish to the counting window was not properly installed and probably accounts for most of the discrepancy.

In recent years, counts of steelhead have been much higher at John Day Dam than at McNary Dam, with the discrepancy as large as 80,000 fish in 1999 (48.9% of the count at JD Dam). In 1996 and 1997, the count discrepancies were 31,800 and 27,200 steelhead (20% and 17% of the counts at JD Dam). During those two years, we released and monitored steelhead with radio transmitters. In 1996 and 1997, 486 and 593 steelhead with transmitters passed John Day Dam, and 415 and 524 fish passed McNary Dam. The discrepancies in passage of steelhead with radio transmitters were 63 and 66 fish for the two years (14% and 12%). In 1996 all but 22 of the 63 fish discrepancy could be accounted for by fish entering tributaries, harvested, or returning downstream from John Day Dam. In 1997, all but 13 of the 66 fish discrepancy could be accounted for. The unaccounted for fish amounted to 5% and 2% of the steelhead with transmitters that passed over John Day Dam. In 2000, the count discrepancy was larger in the two previous years, with a more than 70,000 fish difference (42+% of the count at JD Dam). An preliminary analysis of steelhead with transmitters released in 2000 will be available at the review.

Passage of Adult Salmon and Steelhead through Juvenile Bypass Systems at Bonneville, John Day, McNary and Ice Harbor Dams as Assessed with Radio Telemetry

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We monitored the juvenile bypass systems of Bonneville, John Day, McNary and Ice Harbor dams for fallback events by radio-tagged adult salmon and steelhead in 2000. We determined the number of fallback events, the proportion of total fallbacks that occurred through the juvenile bypass system at each dam, and re-ascension rates for salmon and steelhead falling back via the juvenile bypass system.

Adult Sockeye Tagging at Lower Granite Dam and Tracking to Redfish Lake

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Adult Sockeye were outfitted with radio transmitters at Lower Granite Dam from 25 June 2000 to 25 July 2000. The fish were randomly selected for tagging and outfitted with a 22mm X 9.5mm, 3-volt Lotek radio transmitter. Thirty-one adult sockeye were tagged, released back into the ladder, and their migrations recorded by fixed site receivers and boat and truck tracking. All radio-tagged fish, identified by a CWT, were destined for the upper end of the Salmon River in the Stanley Basin, ID. Seven of the 31 (23%) tagged adults were recaptured at either the Redfish Lake Creek weir or Sawtooth Fish Hatchery weir, and one tag (regurgitated) was found just downstream from the Redfish Lake Creek weir; 26% of the tagged fish were known to have made it back to where they were released or migrated from as smolts. Two mortalities were confirmed, one in the recovery area at Lower Granite Dam and the second at Chief Timothy State Park on the Snake River approximately 37 miles upstream from Lower Granite Dam. The remainder of the fish were last recorded between Lower Granite Dam and Stanley Basin. A secondary tag was not put into the fish, so we are unable to determine if the remaining fish regurgitated their transmitters then completed their migration or if they died near the location of last record. At Lower Granite Dam, 282 sockeye salmon were counted during 2000, and 243 (86%) of those fish were recaptured at the two weirs in Stanley Basin. Migration rates from Lower Granite Dam to first observation at one of the weirs, averaged 18 km\day. Water temperatures throughout the tagging period ranged from 17.9 to 21.5 C and flows were 33.6 to 45.7 kcfs in the Snake River.

Effects of Weir Modifications on Passage of Chinook Salmon Through the Transition Pool at Lower Granite Dam, Spring 2000

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Adult salmon and steelhead spend a significant amount of time passing through the transition pools at the bottom of the ladders when they pass dams in the Columbia and Snake rivers. Typically, a third of the fish pass through transition pools without much delay, and two-thirds turn around and leave the transition pools to move back down the collection channels or move back out into the tailraces. It is unknown why this area in the fishways disrupts fish passage. Low flow velocities through the transition pool area relative to velocities at fishway entrances and in the ladders is one possible cause. There is evidence that most adult salmon and steelhead pass weirs in the ladders through the submerged orifices, rather than over the weirs. When weirs at the bottom of the ladders are submerged because of high tailwater levels, flow through orifices of the weirs is relatively small and velocities may not be adequate to attract the fish.

In 2000, the bottom five weirs in the transition pool at Lower Granite Dam were modified so that a preferred head could be maintained at each weir to increase velocities through submerged orifices. The hypothesis was that with significant flows through the underwater orifices the fish would find them more easily and move into the ladder without delay. A plate was added to increased the height of the center non-overflow section of the first five weirs, and a framework for vertical stop-logs that could be added as needed to reduce the width of the overflow section. These modifications allowed us to maintain a head of 0.25 ft or more at each weir in the lower end of the ladder, and thereby forced more water through the submerged orifices of each weir. A head of 0.25 ft produces a velocity of around 4 fps through the submerged orifices. Weirs were modified by mid-May 2000 and have been in operation since. We monitored adult spring, summer, and fall chinook salmon, and steelhead with transmitters at Lower Granite Dam to evaluate the effectiveness of the weir modifications to improve passage through the transition pool. Passage rates at Lower Granite Dam for spring chinook salmon in 2000 were compared to those in 1996 (the only other year with comparable transition pool data). We also compared passage times at Lower Granite Dams with time-to-pass-the-dam rates for spring chinook salmon at Little Goose Dam during 1997 and 2000.

In 2000, spring chinook salmon with transmitters moved through the transition pool at Lower Granite Dam faster (median of 0.5 hr) than during 1996 (3.5 hr). Total time to pass Lower Granite Dam was also faster in 2000 (19.6 hr) than during 1996 (39.0 hr) and 1997 (24.5 hr), before weirs were modified. It is unclear, however, if faster transit times in 2000 were related to the weir modifications or to better flow and passage conditions (lower and less turbid flow) as compared to 1996 and 1997 since passage at Little Goose Dam was also faster for spring chinook salmon in 2000 (13.3 hr) than during 1997 (20.9) without any weir modifications.

An Evaluation of Cool Water Releases From Dworshak Dam on Adult Migration Through Lower Granite Pool

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During late August and early September, we outfitted 20 hatchery steelhead *Oncorhynchus mykiss* with radio-data storage tags (RDST) that were trapped and tagged at the adult fish trap at Lower Granite Dam and released them back into the ladder to continue their migration. Fish were tracked intensively by boat and truck from Lower Granite Dam through the confluence of the Snake and Clearwater rivers for 14 days. Eighteen out of the 20 fish were located through mobile tracking at least once. However, we were only able to obtain good location data on nine of the fish and we were unable to successfully track fish by boat through the confluence of the Snake and Clearwater rivers. The fish appeared to migrate deep enough much of the time so that the radio signal was difficult to receive. The tagged fish must be recaptured and the RDST tag recovered to get the data needed to determine the depth and temperature of water profiles for the fish as they migrated through the reservoir. In 2001, we plan to use a different tag (combination acoustic and radio) that will allow us to track the fish continuously in the reservoir.

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